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Analogical Reasoning: A Process for Fostering Learning Transfer from the Classroom to Clinical Practice

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University of Connecticut, 2010

ABSTRACT

Context: One of the most common instructional methods utilized in allied health and medical education to promote learning transfer is examination of a single patient case. However, in non-healthcare settings this practice has shown to be less effective in promoting learning than examination of multiple cases with cueing. **Objectives:** To examine the extent of learning transfer of cued versus non-cued pre-professional healthcare undergraduates engaged in a case-based analogical reasoning exercise and to determine what factors may explain variance in transfer outcomes. Additionally, the outcomes of this study will provide the athletic training educator and ATEP administrators' rationale and methods for implementing a case-based analogical reasoning pedagogical approach to improve learning transfer. **Method:** Quasi-experimental randomized post-test design. Participants included 192 pre-professional undergraduates (83 men, 109 women; mean age = 19y, range = 17-33y, SD = 1.73). Cued participants (n = 98) received written cues to compare two heat-illness cases for solution of a hypothermic case, whereas non-cued participants (n = 94) received no cueing. Independent-sample t-test analysis and effect size of mean difference was calculated to assess extent of transfer on a scale of 0-3 for cued and non-cued participants. **Results:** Cued participants (M = 2.30, SD = .89) demonstrated significantly more transfer

(t (175.91) = 2.65; p = .009; CI_{95} = (.10, 0.68); d = .39) of the structural principle than non-cued participants (M = 2.14, SD = .86). There was no statistical difference in transfer of treatment method between cued (M = 1.9, SD = 1.14) and non-cued (M= 2.03, SD = .90) participants (t (190) = .874; p = .38; CI_{95} = (-0.14, 0.36); d = .13). **Conclusion:** Learning transfer is improved among pre-professional undergraduate students during a case-based analogical reasoning process when they are cued to look for the shared structural principle common to the worked cases. Students exposed to multiple case examination with cueing may be more apt to recall their learning and apply it when faced with novel cases in the clinical environment. **Key Words:** transfer of learning, analogical reasoning, cueing

Analogical reasoning: A process for fostering learning transfer from the classroom to clinical practice

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Analogical reasoning: A process for fostering learning transfer from the classroom to clinical practice

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When I was growing up I would had never imagined that I would earn a Ph.D. My mother and father divorced when I was six, leaving the responsibility on my Mother to rear myself and my three other siblings under difficult circumstances. My Mother had never had a job, driven a car or completed her high school education. From the time of the divorce to the completion of my undergraduate degree our family experienced many of the challenges and struggles that comes with a family disadvantaged from a divorce and financial hardship. However, my Mother went on to gain her GED and secured a successful career in property management and based on her life experiences, she always emphasized to me that I could accomplish anything I set my mind to, which has been a driving mantra for me throughout my life and which carried me through my doctoral study.

My wife, Stephanie, was also a driving force during my doctoral study, constantly encouraging me to persevere when challenges arose and there were many. More importantly, she agreed to give a great deal of herself to support my doctoral pursuit. For the past 5 years she served as the primary caregiver of our two children, while I either spent my weekends in the library or was away from home, researching, writing, or attending classes. In essence, she put her life on hold to support me. Thank you Stephanie for not only enabling me to be successful in this pursuit, but for keeping our family happy, healthy and cohesive.

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CHAPTER I

Introduction

In 1999, 44,000 to 98,000 deaths occurred in the United States because of medical error, more than the number of deaths caused by breast cancer, AIDS, or vehicular accidents (Kohn, Corrigan & Donaldson, 1999). From 1999-2003, one-fourth of adults experienced a medical error (Sage, 2003). In 2001, the Institute of Medicine (IOM), a committee of physicians and health policy experts charged to improve the health of the Nation by the National Academy of Science, identified a gap in the area of education of health care practitioners as one of the reasons for medical error. The identified gap by the IOM prompted the need to overhaul clinical education at all levels. Moreover, public recognition of medical errors crystallized concerns that health care students are not effectively transferring their classroom learning to clinical practice (Battles & Shea, 2001; Shine, 2002). Traditional instructional strategies are insufficient to enable students to transfer what they have learned in the classroom (Weeks, Lyne & Torrance, 2001), or to address novel clinical problems they will face as future health care professionals (Shine, 2002).

Problem Statement

Transfer of learning has been characterized as the ability to use knowledge or skill obtained in one context to solve a problem in another, either similar in nature, known as near transfer, or dissimilar in context, termed far transfer (Barnett & Ceci, 2002). In allied health and medical education, instructors expect students will acquire the ability to transfer their classroom learning of patient cases to solve novel clinical problems in practice (Radtke, 2008; Shine, 2002). One of the most common instructional methods that has persisted to promote transfer and problem-solving has been the examination of a single patient case (Shine, 2002), a pedagogical practice shown to be ineffective (Gentner, Loewenstein & Thompson, 2003; Norman, Krebs & Neville, 2007). However, researchers have demonstrated that use of multiple case examples with instructor cueing (prompting or provision of hints) is superior for fostering transfer of learning to enable novel problem solving (Gentner et al., (2003); Norman, et al., 2007).

Research findings such as these are particularly relevant today. Medical knowledge doubles every 6-8 years, far outpacing traditional methods of educating healthcare practitioners (Mantovani, Castelnuovao, Gaggioli & Riva, 2003). Healthcare practitioners must have the ability to solve novel clinical problems; however, they may not have the essential skills to attain this goal in light of how they are educated coupled with the rate of medical knowledge expansion. Moreover, traditional instructional practices such as singular case examination may result in a lack of problem-solving skill and mental flexibility early in the student's training, impeding transfer either near or far from the classroom to clinical practice, promulgating medical error (Shine, 2002).

Eliminating medical error is not possible because human error is inevitable, but it can be limited (Al-Assaf, Bumpus, Carter & Dixon, 2003). One way to limit error identified by the IOM (2001), researchers, and educators (Norman, et al., 2007; Weeks, Lyne & Torrance, 2000; Weeks, Lyne, Mosely & Torrance, 2001) is effective education of health care students and professionals. Al-Assaf, et al. (2003) advocated addressing medical error directly with those who provide care. However, to move closer to addressing one of the roots of the medical error phenomenon, starting with those who educate our health care students is a priority.

An instructional approach such as case-based analogical reasoning with cueing is an alternative pedagogical approach that has been advocated to bridge the learning transfer gap from the classroom to clinical practice setting (Norman, et al., 2007) and to promote the mental flexibility practitioners need today for solving novel clinical problems (Shine, 2002). The challenge for health care educators is to *foster* learners' transfer of a classroom learning experience to clinical practice in order to curb the incidence of medical error.

As a first step to address this challenge, three papers follow which examine the effectiveness of cueing on the case-based analogical reasoning process. The first, published in the journal of *International Forum of Teaching and Studies* in 2009, proposed three propositions and a theoretical model to support the role of cueing in the case-based analogical reasoning process and how it can be optimized to improve learning transfer. The second paper, currently under review by the *Journal of Academic Medicine,* presents empirical findings of a study conducted to examine if cueing during a case-based analogical reasoning process improves transfer of learning among pre-professional healthcare students, in part, supporting the theoretical model introduced in the first paper. Based on the second paper's findings and cognitive literature, the third paper provides the athletic training educator a sound rationale and "blue print" for implementation of case-based analogical reasoning pedagogy to improve learning transfer among athletic training students. The plan for this paper is to submit it to the *Athletic Training Education Journal.*

CHAPTER II

Analogical reasoning: A process for fostering learning transfer from the classroom to clinical practice

Introduction

In 1999, 44,000 to 98,000 deaths occurred in the United States because of medical error, more than the number of deaths caused by breast cancer, AIDS, or vehicular accidents (Kohn, Corrigan & Donaldson, 1999). From 1999-2003, one-fourth of adults experienced a medical error (Sage, 2003). In 2001, the Institute of Medicine (IOM), a committee of physicians and health policy experts charged to improve the health of the Nation by the National Academy of Science, identified a gap in the area of education of health care practitioners as one of the reasons for medical error. The identified gap by the IOM prompted the need to overhaul clinical education at all levels. Moreover, public recognition of medical errors crystallized concerns that health care students are not effectively transferring their classroom learning to clinical practice (Battles & Shea, 2001; Shine, 2002). Traditional instructional strategies are insufficient to enable students to transfer what they have learned in the classroom (Weeks, Lyne & Torrance, 2001), or to address novel clinical problems they will face as future health care professionals (Shine, 2002).

Problem Statement

Lecture-based teaching has been one of the traditional teaching methods attributed to poor problem solving ability among health care students (Shine, 2002; Weeks, Lyne, Mosely & Torrance, 2000). For example, Weeks et al. (2000) found a failure of traditional lecture to promote transfer of critical life-saving knowledge among United Kingdom student nursing cohorts (*N*=392). In this study 58.5% of students made drug dosage calculation errors and after three remedial trials reached only 78% proficiency. The authors identified traditional lecture-based practices as a primary barrier for transfer of problem solving skills needed for calculation of drug dosages.

Additionally, one of the most common instructional methods in medical education to promote problem solving with novices who possess limited real-world clinical experience is examination of a patient case (Shine, 2002). However, researchers (Gentner, Loewenstein & Thompson, 2003; Norman et al., 2007) have demonstrated that use of multiple case examples with instructor cueing (prompting or provision of hints) is superior to a single case example and essential for fostering transfer of learning to enable novel problem solving. Traditional instructional practices such as singular case examination may result in a lack of problem solving skill and mental flexibility, impeding transfer of classroom learning to clinical practice, and promulgating medical error (Shine, 2002).

Eliminating medical error is not possible because human error is inevitable, but it can be limited (Al-Assaf, Bumpus, Carter & Dixon, 2003). One way to limit error identified by the IOM (2001), researchers, and educators (Norman, et al., 2007; Weeks, et al., 2000; 2001) is effective education of health care students and professionals. Al-Assaf, et al. (2003) advocated addressing medical error directly with those who provide care. However, to move closer to addressing one of the roots of the medical error phenomenon, starting with those who educate our health care students is a priority.

The predominant mode of continuing education of health care practitioners once they enter the workforce is through classroom-based instruction (Shine, 2002). Health care practitioners must have the ability to solve novel clinical problems. However, adult learners in health care may be ill-equipped through traditional classroom instructional strategies to not only transfer what they have learned in the classroom (Norman, et al., 2007; Weeks, Lyne & Torrance, 2001), but may also lack problem solving skills needed to address novel clinical problems through traditional pedagogical approaches (Battles & Shea, 2001; Shine, 2002). An instructional approach such as case-based analogical reasoning with cueing is an alternative pedagogical approach that has been advocated to bridge the learning transfer gap from the classroom to clinical practice setting (Norman, et al., 2007) and to promote the mental flexibility practitioners need today for solving novel clinical problems (Shine, 2002).

The challenge for health care educators is to *foster* learners' transfer of a classroom learning experience to clinical practice in order to curb the incidence of medical error. As a first step to address this challenge, this paper examines the effectiveness of cueing on the case-based analogical reasoning process and proposes a theoretical model to improve transfer of learning.

Conceptual Framework

After conducting a review of transfer of learning and analogical reasoning literature, a model that nested the concepts together with the instructional intervention of cueing was not present. Therefore, to fill this gap in the literature, the Perception of Applicability Model (Figure 1.) was constructed to represent the role of cueing on promoting learning transfer.

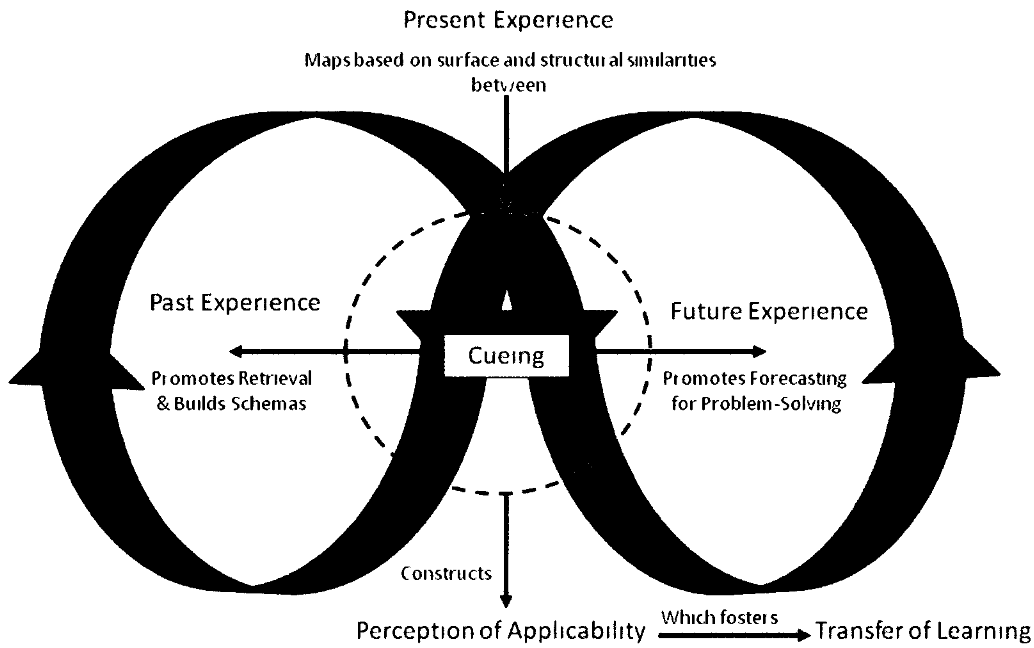

Figure 1. Perception of Applicability Model

However, the Trio Model of Adult Learning (Sheckley, Kehrhahn, Bell, & Grenier, 2007) served as the foundation and impetus for the conceptualization of the model in its early stages, particularly Trio's emphasis on key experiences to promote cognitive processes involved in analogical reasoning (Figure 2). Cueing by the instructor during case-based analogical reasoning is a key experience for learners because it helps them recall and map past experiences to their present.

Cueing can also promote students' forecasting of the match between past and present experiences for problem solving and goal attainment, thereby, constructing a perception of applicability of their learning experiences for meaningful application and transfer. Following are three propositions, which evolved from empirical evidence to support the intervention of cueing during the case-based analogical reasoning process.

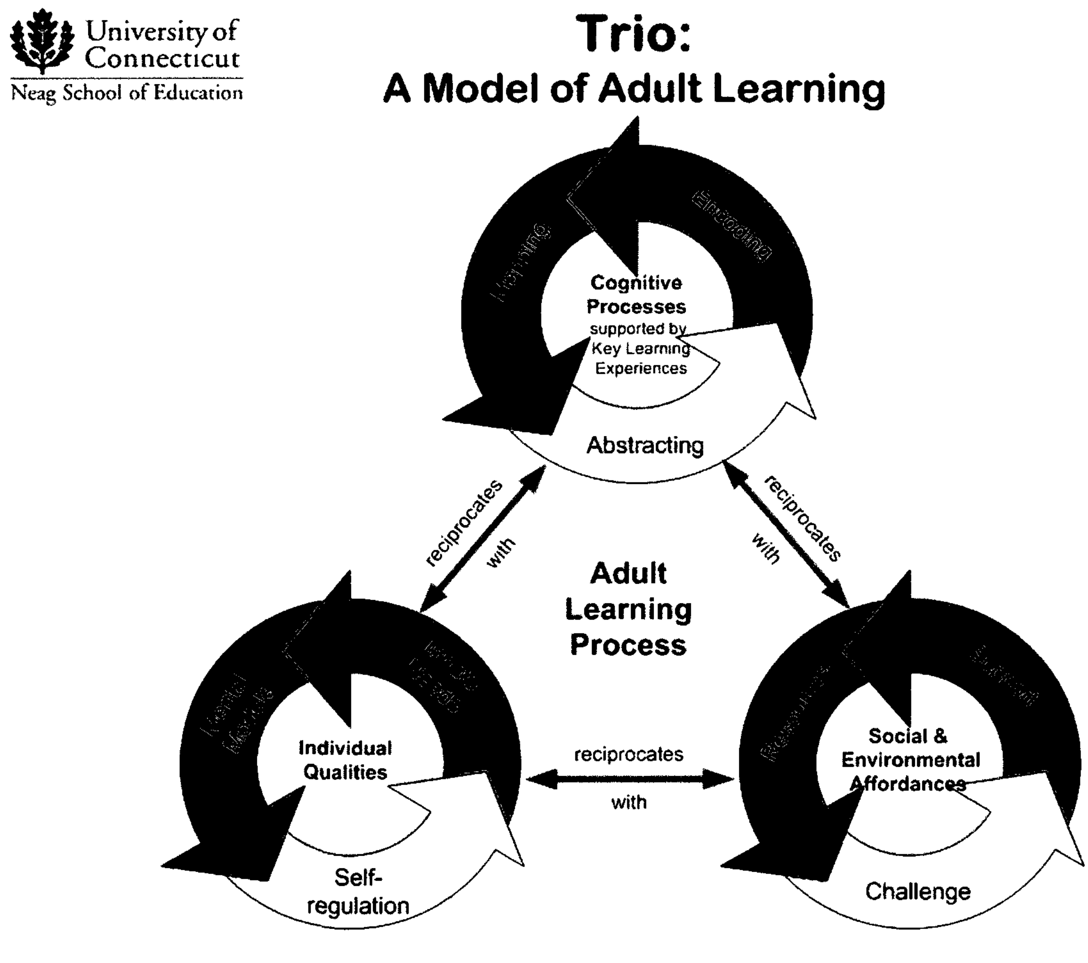

Figure 2. TRIO Model of Adult Learning

Proposition 1: Learning Transfer is fostered when quality schemas are developed.

A schema is an abstract representation of a concept or experience and its associated properties; it is a bundle of knowledge about an experience, the more connections made, the higher quality the schema (Reed, 1996). An essential method in promoting analogical transfer is to provide the learner with key experiences (schema), which build their mental models to foster problem solving skills (LeGrow, Sheckley, & Kehrhahn, 2002). When we have an experience, we make sense of the experience by searching our relevant prior experiences to contrast and compare them to the present based on their surface and structural features (mapping)—if a problem exists, we extend the mapping to the problem (target) to be solved (Holyoak & Koh, 1987). Findings in health care and non-health care disciplines suggest when novices lack robust schemas; novel problem solving is limited (Norman et al., 2007; Novick, 1988), but can be overcome by using multiple sample cases to serve as base exemplars for novel problem solving (Norman et al., 2007; Novick & Holyoak, 1991; Shayo & Olfman, 2000).

The use of multiple case examples demonstrates the power for developing a novice's schema quality to solve novel problems, but also the necessity of the learner to perceive them as applicable for successful analogical reasoning and learning transfer to occur. Shayo and Olfman (2000) demonstrated use of multiple examples among novices enhanced schema quality to solve novel problems. The authors examined undergraduate seniors (N=44) who had previous database and processing experience to determine to what extent two versus one database training case example in either a relevant or generic context would affect schema quality and use of a novel database. Large to moderate effect sizes[1] for improved schema quality were found among subjects who received training with two database examples over subjects who received one in either a generic (ES_r =.85) or relevant context (ES_r = .40). Moreover, a large effect size (ES_r = .86) for an ability to successfully use a novel database was observed between subjects who received relevant examples over those who did not. This study showed the value of multiple case examples in successful analogical reasoning and transfer of learning and the necessity of learners to perceive that the cases are applicable.

In traditional medical education, acquiring knowledge often precedes understanding its application, thus leaving individuals unsure if they really need to learn and transfer their learning. Yelon, Sheppard, Reznich and Sleight (2004) conducted a qualitative study on how teaching fellows (N = 73) formed the intention to transfer their fellowship training. A rich base of prior experience from which to compare proposed teaching ideas not only promoted their intention to transfer an idea, but also enabled fellows to see the applicability or fit between the idea and their experiences for attainment of future goals or solution of a problem. As illustrated in Figure 1. and articulated in proposition one, the ability of learners' to optimally compare their past and present learning experience and its applicability for solving problems is dependent upon rich past learning experiences. In sum, provision of relevant multiple case examples can assist in the development of quality schema, which serve an essential role in fostering learning transfer because they serve as a base from which individuals compare and

[1] Cohen's (1988) effect size (ES_r) conventions in Lipsey & Wilson (2001) are described as: small (.10 - .28), medium (.29 - .50) and large (.51- >).

contrast past and present experiences in order to assess applicability to problem solving and future experiences.

Proposition 2: Learning Transfer is fostered when the learner is prompted to identify shared structural relations between a base and target analog.

Empirical studies have shown the effectiveness of using analogical reasoning to solve novel problems relies on learners' ability to identify the common structural relationship between base and target analogs (Gentner, Lowenstein & Thompson, 2003; Novick, 1988). According to Gentner's Structure Mapping Theory (1983), drawing an analogy between two examples leads to a structural alignment between them promoting abstraction of schemas, thereby, facilitating improved recall and transfer of learning. Gentner, et al. (2003, Experiment 1) found the ability of undergraduates ($N = 48$) to transfer an optimal negotiation principle for solution of a novel negotiation problem hinged on whether case examples examined shared a structural relationship. Subjects guided to compare cases containing a structural relationship proposed the optimal structural negotiation principle more than subjects not prompted to compare cases ($ES_r =$ .57).

As observed with Gentner et al. (2003, Experiment 1) findings, earlier work by Holyoak and Koh (1987, Experiment 2) on structural relationships also demonstrated undergraduate students ($N = 63$) problem solved more effectively when asked to compare two structurally similar examples, particularly, when provided guidance in finding the structural principle between the examples. Subjects compared story analogs containing either high or low structural and surface similarity. Transfer of the principle for solution of the target was significantly compromised if either surface or structural similarity was reduced (*ES_r* = .38 & .44, respectively). However, once a hint was given only structural dissimilarity in the base analogues decreased transfer (*ES_r* = .26). "Detection of an analogy based solely on abstract structural features may be a rare event for novice problem solvers" (p. 338), therefore, necessitating deliberate cueing (Holyoak & Koh, 1987). Learners' map experiences based on their surface or structural characteristics as seen in Figure 1., however, as discussed in proposition two, problem solving and learning transfer is improved when learners' are prompted to examine the structural relationship they share, which requires cueing.

Proposition 3: Learning transfer is fostered when cueing is utilized to facilitate base analogue retrieval and mapping.

Cueing the learner to search for either surface or relational connections between current and past experiences promotes identification of correspondences between base and target analogues, promoting both retrieval and mapping for successful analogical transfer and problem solving (Gentner, et al., 2003; Novick & Holyoak, 1991). However, identification of structural similarities serve the primary role in the analogical transfer process *after* relevance of the base and target analogues have been recognized via the provision of a hint as observed by the medium effect size found in experiment 2 by Holyoak and Koh (1987), discussed earlier. Cueing is critical when prompting individuals to identify structural relationships between analogues because it cues the learner to pay attention to the relationship among analogues for solution (Holyoak & Koh, 1987). Cueing learners to identify the relationship between analogues facilitate dissociation of the surface and structural relationship of the examples—the structural relationship serving a more powerful tool for problem solving (Gentner & Markman, 1997; Norman, et al., 2007).

Use of multiple case comparison and instructor cueing can compensate for a lack of relational experience in novices. Norman, et al. (2007) demonstrated extremely large effect sizes for improved transfer by prompting health science undergraduates (N= 35) to examine the relational structure among multiple case examples rather than utilizing one example alone to solve a target problem. When subjects were prompted to compare multiple examples, they transferred their underlying concepts to solve new clinical problems significantly better than those presented with multiple examples with no cueing ($ES_r = 1.36$). The group which received only one example and no prompting did worse in comparison to the prompted group which received multiple examples ($ES_r = 1.74$).

As depicted in the Perception of Applicability Model (Figure 1.) and discussed in proposition three, cueing serves the central role in assisting learners' to identify, recall and map their experiences to determine how they can be utilized for problem solving. Moreover, cueing facilitates identification of the structural relationship between case examples, enhancing problem solving and learning transfer (Gentner, Loewenstein & Thompson, 2003; Norman et al., 2007).

Conclusion

Educational preparation of health care practitioners requires reexamination. The traditional measure of providing singular patient case examples is ineffective in comparison to having learners' compare structurally similar cases with instructor cueing (Norman et al., 2007). If health care educators understand the factors which impact the formation of a perception of applicability of a learning experience and methods by which to facilitate it when using case examples, they can assist the learner to transfer their learning from the classroom to the clinical environment, thereby, possibly reducing the rate of medical error.

Implications for Practice

1. Educators' should identify the learner's level of experience with the instructional or case content. Identification of experience level will assist the educator to determine the extent of cueing needed to assist the learner in the case-based analogical reasoning process.
2. Novices' will require deliberate cueing during the case comparison process in order to foster their identification of the structural principle inherent in the cases for problem-solving application and future use in the clinical setting.
3. Use of relevant comparison cases with instructor cueing should occur in the education of health care practitioners. This practice will help learners' identify the applicability of the inherent structural principle for potential application and will build context specific schema of learners' for future problem solving.

The challenge for educators of health care students and practitioners is to construct and facilitate learning experiences that capitalize on identification of structurally relevant case comparison examples for solution of future clinical problems. The Perception of Applicability Model is a first step towards establishing a foundation from which to examine to what extent and in what ways multiple case-based examinations with cueing can improve transfer of learning and problem solving to reduce the incidence of medical error rampant in the health care system.

CHAPTER III

Effect of cueing on learning transfer among pre-professional undergraduate healthcare students engaged in a case-based analogical reasoning exercise

Transfer of learning has been characterized as the ability to use knowledge or skill obtained in one context to solve a problem in another, either similar in nature, known as near transfer, or dissimilar in context, termed far transfer (Barnett, 2002). In allied health and medical education, instructors expect students will acquire the ability to transfer their classroom learning of patient cases to solve novel clinical problems in practice (Radtke, 2008; Shine, 2002). One of the most common instructional methods that has persisted to promote transfer and problem-solving has been the examination of a single patient case (Shine, 2002), a pedagogical practice shown to be ineffective (Gentner, Loewenstein & Thompson, 2003; Norman, Dore, Krebs & Neville, 2007). However, researchers have demonstrated that use of multiple case examples with instructor cueing (prompting or provision of hints) is superior for fostering transfer of learning to enable novel problem solving (Gentner, Loewenstein & Thompson, 2003; Norman, Dore, Krebs & Neville, 2007).

Research findings such as these are particularly relevant today. Medical knowledge doubles every 6-8 years, far outpacing traditional methods of educating healthcare practitioners (Manovani, Castelnuovo, Gagglioli & Riva, 2003). Healthcare practitioners must have the ability to solve novel clinical problems; however, they may not have the essential skills to attain this goal in light of how they are educated coupled with the rate of medical knowledge expansion. Moreover, traditional instructional practices such as singular case examination may result in a lack of problem-solving skill and mental flexibility early in the student's training, impeding transfer either near or far from the classroom to clinical practice, promulgating medical error (Shine, 2002).

Novice and Expert Learners

To solve novel clinical problems and to avoid medical error, novice and expert practitioners alike must not only be able to recall declarative knowledge (e.g., signs and symptoms of a condition), but must also be able to recall and apply associated concepts or structural principles they may never have explicitly studied. When two or more examples are compared, the learner aligns the correspondences between them to form a shared relationship or principle (Gentner, Loewenstein & Thompson, 2003). For example, a cell phone and two-way radio both have different surface features, however, both share the structural principle of a tool that can be used for communication. Once the shared principle has been identified, it can then be utilized to solve novel problems (Gentner, Loewenstein & Thompson, 2003). But because expertise development unfolds over time (Ericsson, 2004), the expectation that entry-level health practitioners will have an exceptional ability to solve novel problems through the use of structural principles in the clinical setting is unrealistic (Battles & Shea, 2001).

Chi et al. (1981) demonstrated that experts are better problem solvers because they rely more heavily on structural principles or concepts for problem solving than novices, who primarily rely on surface similarities, such as patient appearance. Researchers attribute this distinction to higher schema quality (Gentner, Loewenstein & Thompson, 2003; Novick, 1988; Novick & Holyoak, 1991; Shayo & Olfman, 2000). A schema is an abstract representation of a concept or experience and its associated properties; it is a bundle of knowledge about an experience, the more connections made, the higher quality the schema (Reed, 1996). Schemas are analogous to bricks, the mortar holding them together formed from reasoning about problems; the greater amount, the higher quality the individuals' mental foundation or mental model by which to compare and solve new problems.

LeGrow, Sheckley & Kehrhahn (2002) reported that adults who lack a foundation of experience in the business world have difficulty solving a posed business problem. The authors compared two groups (N=54) of graduate students from a business management program. They observed a large effect difference (d = .85) among groups. Those credited with prior learning in business settings (non-traditional students) demonstrated an ability to form more intricate solutions to problems than traditional students. When posed a "real-life" business problem, the non-traditional students recalled and mapped it more effectively on the basis of their prior business experience. The process of mapping involved the alignment of past and present experience.

The authors concluded the experience non-traditional students gained in the business world fostered the development of higher-quality schema and mental models, resulting in an enhanced ability to analogically reason about the posed problem, enabling them to apply solutions observed or experienced in the past. In contrast, traditional students with less developed schema demonstrated an inferior ability to generate more developed solution procedures. These findings reinforce the experiential nature of the mapping and abstraction process that over time creates analogical integration of schema and mental models for successful problem solving (Edelman & Tononi, 2001). Predictably, novice healthcare students typically possess a weak schema foundation because they have had limited field experience and therefore, limited opportunity to analogically reason about relevant clinical problems.

Schema Development

A method known to assist novices in developing schema is comparison of multiple case examples. Multiple case comparison has been advocated in medicine (Norman et al., 2007) as it is likely hazardous to allow novices to train on real patients without prior understanding of their actions. Novick (1988) proposed that the ability of the learner to retrieve a like problem and adapt its solution to a conceptually similar problem rests on schema quality, linked to the learner's level of expertise in the associated domain. Individuals with more developed knowledge structures are able to adapt and apply them to complex multi-step procedures for use in successful analogical transfer (Novick), a skill needed by medical practitioners when faced with novel clinical problems (Sage, 2003).

According to several studies (Gentner, et al., 2003; Norman, et al., 2007; Shayo & Olfman, 2000), exposing novices to comparison of multiple case examples for the purpose of applying their shared structural principle assists in the development of quality schema, in spite of lack of real-life experience. Gentner et al. (2003) explored whether comparison of analogical cases for novel problem solving of a business negotiation improved analogical encoding among novices. Analogical encoding involves the comparison of two similar but distinct examples with a common underlying principle for application to a target problem (Gentner et al., 2003). Even though two examples can be highly unrelated to an individual's past experience, the process of comparing them and uncovering the common structural principle builds the learner's schema and problem-solving ability (Gentner et al., 2003; Norman et al., 2007). Undergraduates (N=128) were randomly assigned to separate-case (the controls) and multiple-case comparison groups and were provided with two cases containing examples of negotiation contracts dissimilar in surface features (e.g., type of business setting) but similar in an optimal negotiation principle. Those in the multiple-comparison group when prompted to compare cases to derive the optimal negotiation principle outperformed the control group; they transferred the optimal principle to the test condition twice as frequently (d = .63). Additionally, 42% were able to state the underlying structural principle more fully than the control group (d = 1.01), and 98% linked the two-case examples as compared to 16% of participants in the control group. Moreover, small to medium effect sizes were associated with higher quality schemas (d = .24) and improved analogical transfer (d = .49). Simply, the multiple-case comparison group learned the underlying principle in the two cases and transferred it to solve a novel situation better than those who did not compare cases. The authors concluded: "The overall pattern of findings is consistent with our claim that analogical encoding leads to better learning, which in turn leads to superior transfer" (Gentner, et al., 2003, p. 400). Although engaging novice learners in comparing multiple-case examples is beneficial for schema development, successful problem solving and transfer (Gentner, et al., 2003; Norman et al., 2007; Novick, 1988), cueing during the process results in significantly better transfer outcomes (Gick & Holyoak, 1983; Norman et al., 2007; Novick & Holyoak, 1991; Shayo & Olfman, 2000).

Cueing and Why it Works

Instructors serve a central role in the case-based analogical reasoning process because they not only cue the learner to identify structural relationships that exist between the cases being compared and the learner's past experiences, but also how these relationships may solve future problems (Shayo & Olfman, 2000; Speicher & Kehrhahn, 2009; Yelon, Sheppard, Sleight & Ford, 2004). Speicher and Kehrhahn (2009) proposed a model (Figure 1) that supports the intervention of cueing during the case-based analogical reasoning process to foster learning transfer. The cueing intervention helps learners retrieve and map their present learning experience with their past experience. This mapping process helps to not only build an individual's schema but the match between both develops in the student a perception of being able to apply the learning experience to a current or future problem. For example, even though healthcare students may appreciate the need to know the signs and symptoms and subsequent treatment for patients experiencing heat illness, they may not "see" the structural relationship shared among multiple patients in heat distress (e.g., inadequate regulation of core body temperature) unless cued to look for the relationship. Moreover, they may not understand how the relationship could help them solve a future dissimilar—though conceptually related—case, such as management of a hypothermic patient that involves the same principle. Even though a student may never have worked with patients experiencing heat illness, the case-based analogical reasoning process coupled with a cueing intervention serves to fill this gap.

Use of multiple case comparison and instructor cueing can also assist novices to focus on the structural rather than surface attributes of cases (Holyoak & Koh, 1987). Norman et al. (2007) demonstrated large effect sizes for improved transfer by prompting health science undergraduates (*N*= 35) to examine the relational structure among multiple case examples rather than utilizing one example alone to solve a target problem. When participants were prompted to compare multiple examples, they transferred their underlying concepts to solve new clinical problems significantly better than those presented with multiple examples without cueing ($d = 1.36$). The group that received only one example and no prompting did worse in comparison to the prompted group that received multiple examples ($d = 1.74$). Holyoak and Koh (1987) asserted that providing the learner with prompting is a critical instructional technique for moving the student to identify structural relationships among multiple analogues or examples because it alerts the learner to look for the relationship that exists among analogues for solution. The findings of this study affirm the benefit of assisting students to dissociate surface from relational attributes among multiple-case examples. Without doing so, novice learners often will use surface attributes to form their target or case solution (Novick & Holyoak, 1987; Shayo & Olfman, 2000), shown to be less effective for problem-solving than use of structural principles (Gentner et al., 2003; Shayo & Olfman, 2000).

Utilizing case-based analogical reasoning with cueing in the formative years of a healthcare providers training provides them a foundation from which to pull when faced with novel clinical problems (Robins & Mayer, 1993). Further, cueing during the analogical reasoning process will help future healthcare providers identify and learn structural principles for application to future novel clinical problems they are likely to encounter in an ever-changing healthcare environment.

The purpose of this study was to examine the extent of learning transfer of cued versus non-cued pre-professional healthcare undergraduates engaged in a case-based analogical reasoning exercise and to determine what factors, if any, explained variance in transfer outcomes.

Method

A quasi-experimental randomized post-test design was utilized (Creswell, 2005). The experimental and control groups compared two worked cases (i.e., cases with solutions) involving patients who had experienced heat illness (Figure 3). The experimental group (cued) received written cues that guided participants to look for a solution common to both cases and to write down how each was similar. The instruction for the control group (non-cued) was to read and write down what was going on in each case separately. Cueing prompts and their presentation format were based on the work of Gentner et al. (2003) and Gick and Holyoak (1983). Additionally, based on procedures used by previous researchers (Gentner et al., 2003) to facilitate case comparison, patient cases for the experimental group appeared on the same sheet of paper with cases for the control group on separate sheets. After examining the cases, each group composed a solution for a third target case involving a hypothermic patient (Figure 4). Imbedded in the worked cases was an implicit shared structural principle (thermoregulation of core body temperature) and optimal treatment method (direct full-body treatment technique) for solution of the third case.

Dependent variables of the study were transfer of (a) the structural principle and (b) the optimal treatment method common to the worked cases, assessed from solution responses to the target case. Transfer was assessed on the basis of the extent of the structural similarity of the solutions provided to those embedded in the worked cases. The independent variable was the cueing intervention. Covariates analyzed were prior experience with case content and geographic location where subjects spent most of their lives.

Please read the following two cases. Comparison of the two cases will help you produce a solution(s) for a third test case.

You are the clinician responsible for a youth soccer camp. A camper approaches you after lunch and complains she does not feel well. She tells you she feels sick to her stomach, is tired, and has a headache.

You notice her breathing is elevated, skin is pale and she is sweating profusely. She is having difficulty standing so you ask her to sit down. You take her temperature and it is 103 degrees Fahrenheit. You move the camper to a cool environment and start your treatment, which consists of placing towels dipped in cold water over her body. You retake her temperature a few minutes after the treatment and it has dropped to 102 degrees Fahrenheit, but the breathing rate and skin color are the same as before.

Case 2:

You are a health care provider at a local road race. As a runner is approaching the finish line, he stumbles and collapses.

When you approach the runner, his face is red. There is no sweat on his body and his breathing is very rapid. You ask him questions, but cannot understand them because his speech is slurred. You move the runner to the medical tent and take his rectal temperature, which is 106 degrees Fahrenheit. You place him in a kiddy pool of cool water. You retake his temperature a few minutes after the treatment and it has dropped to 102 degrees Fahrenheit, the breathing rate has slowed, the face redness has diminished and he is now able to speak a few coherent words.

Think about the similarities between these two cases. What are the key similarities in the two cases? Write them down below.

Figure 3. Worked Comparison Cases with Cues

Provide a solution(s) in writing for this case based on what you have learned thus far from the cases examined.

You enter the hydrotherapy room in the therapy clinic to care for a patient who has "passed out" while receiving a full-body cold whirlpool treatment. Several individuals are assisting him out of the pool, but he appears to be unable to exert any coordinated physical effort to get out even with assistance. You notice the temperature of the whirlpool is 45 degrees Fahrenheit. Upon removing the individual from the pool, you notice his skin is pale, lips are slightly blue, his breathing is extremely slow, but he is shivering. You ask him questions, but cannot understand him because his speech is slurred.

What should you do and why? Be specific as you can.

Figure 4. Target Case with Cues

Sample

The sample consisted of (N= 192) volunteer pre-professional undergraduate students seeking a career in allied health or medicine. Pre-professional healthcare students were selected because case-based patient examination is a foundational method utilized in the educational preparation of healthcare providers (Clark & Harrelson, 2002) and it is a common expectation that healthcare students will transfer their classroom learning of patient cases to solve novel clinical problems in practice (Radtke, 2008). The study occurred at four institutions of higher education in the State of Connecticut, Institutional Review Board approval was obtained at each participating institution. Participants were randomized into either experimental (n = 98; 40 males; 58 females) or control (n = 94; 43 males; 51 females) conditions. Students were college-aged (M = 19 y, SD = 1.73), from the Northeast (92%) and primarily Caucasian (87%).

A demographic and prior experience survey (DPES) was administered and results analyzed with correlation and analysis of variance (ANOVA) to determine if significant difference in demographic and prior experience level existed (Appendix A). No significant differences were found within or between groups revealing a sample homogenous in nature. Variance in transfer scores related to participant prior experience was a concern because Novick and Holyoak (1991) have identified level of experience with case content can affect learning transfer of a structural principle derived from case comparison. The survey was administered post-experiment to prevent unintentional cueing of participants to the case content and structural principle. Prior experience with case content was ascertained via a "yes" or "no" response to six questions about formal and informal exposure to the case content. A "yes" yielded a score of 1 and "no" yielded a 0. Tabulation could yield a maximum score of 6, the higher the score the greater prior experience with the case content. However, no significant differences in prior experience with case content between groups existed.

Data Collection

A pilot study utilizing pre-professional nursing undergraduates (N =51) was conducted to evaluate the readability, validity and reliability of instruments and procedures. A pilot study was performed because assessment of transfer of case-based analogical reasoning involving worked patient cases had not been undertaken before this study. Therefore, two experts in the field of athletic training education with greater than 10 years of experience were selected to evaluate the readability, content and construct validity of instruments in the pilot study and also served as evaluators for this study. Ericsson[8] reported most scientists regard 10 or more years of experience in a domain to be sufficient to build expertise in the particular domain.

The development of the worked cases were based on criteria proposed by Gentner and Colhoun (2010) and Tuovinen and Sweller (1999). Gentner and Colhoun proposed that when constructing cases for analogical comparison, they contain structural soundness, factual validity, and pragmatic relevance. An additional consideration in the construction of the case examples was to avoid cognitive overload common among novices when processing unknown complex material (Tuovinen & Sweller, 1999). Cognitive overload results in a decreased capacity to learn and engage in successful problem solving due to the limited capacity of working memory (Tuovinen & Sweller, 1999). According to Tuovinen and Sweller (1999) if a schema is not present to process the elements of a case, each element will have to be processed individually, resulting in high cognitive overload. Therefore, the cases developed for our study were worked cases. Additionally, worked case examples are a form of task-valid cueing, which provide rich contextual information and engenders the construction of mental models (Hummel & Nadolski, 2002). Worked case examples were most appropriate for the novice participants because they can free working memory and reduce cognitive load (Tuovinen & Sweller, 1999), allowing learners to focus on relevant information and solutions for effective problem solving (Hummel & Nadolski, 2002).

Guided by the work of Gentner and Colhoun (2010), we also developed a learning transfer assessment instrument (LTAI) to determine the extent of transfer of the worked cases' structural principle (thermoregulation of core body temperature) and optimal treatment method (direct full- body treatment technique) to the target third case (Appendix B). A direct full-body treatment technique (i.e., partially submerging the body in cool or warm water) was utilized as the optimal treatment method/approach to regulate core body temperature because it has been shown to be one of the most effective ways to regulate core temperature of patients experiencing heat illness (Casa, 1999).

The LTAI utilized an ordinal scale from 0-3 to determine the extent of structural similarity in participant solutions. A score of 3 indicated a great extent of structural similarity and 0 represented none. Each criterion was accompanied by an exemplar illustration gained from the pilot study. For example, the following participant pilot response was scored as a 0: "*You should immediately take his pulse, body temperature and blood pressure to get a better understanding of what the problem is. His body may have gone into shock due to the cold water and that may not be the treatment needed to cure the patient.*" This solution response lacked application of the thermoregulation principle as well as the optimal treatment method. Whereas, the following response scored as a 3 demonstrated transfer of both the worked cases structural principle and optimal treatment method: "*The patient should be placed in a pool of warm water to raise his body temperature. In one of the previous cases, the patient suffered from similar symptoms but the patient's temperature was too high rather than too low. When placed in a pool of cold water, the patient's temperature decreased, speech became normal, and normal skin color was restored. Since this case is similar except for a lower body temperature, treatment in a warm water pool may be a solution.*"

Intraclass correlation coefficients (ICC) were utilized to assess inter- and intra-rater reliability of the LTAI outcomes. Evaluators' use of the LTAI during pilot testing produced good to excellent ICC inter- and intra-rater reliability. In the pilot study inter-rater reliability for the structural principle was .88 and .96 for the optimal treatment method. Intra-rater reliability for the structural principle ranged from .80 to .93 and .88 to .86 for the treatment method.

Reliability for this study was improved by adding exemplar solution responses from the pilot study to each criterion level. Inter-rater reliability of the structural principle and treatment method were .91 and .95, respectively. Intra-rater reliability ranged from .88 to .93 for the structural principle and from .95 to .96 for the treatment method. As suggested by Portney and Watkins (1993), a .75 ICC value ensures good reliability.

Recruitment of volunteers occurred during pre-professional courses taught at each institution. Participants were randomly assigned to either experimental (cued) or control groups (non-cued). Based on power calculation (Faul, Erdfelder, Lang & Buchner, 2007) at a .05 significance level, .80 power and a moderate effect size of .50, the minimum number of participants needed was 128. Data collection occurred through the LTAI and DPES instruments in a one-time, 30-minute classroom environment. After worked cases were read and responses given, participants were provided the target case to be solved. In order to limit unintentional case comparison within the control group, participants were not permitted to refer back to their worked cases or responses for solution of the third target case.

Data Analysis

Statistical analysis was performed with SPSS v. 16 with an alpha level of .05 (two-tailed) as the criterion for significance. An independent-samples *t*-test analysis of the mean difference was calculated to assess the extent of transfer of the structural principle and treatment method between groups. Additionally, effect sizes were calculated according to Cohen's (1988) conventions. Correlational analysis was performed prior to ANCOVA testing to determine variance in transfer scores based on group assignment, level of prior experience and geographic location.

Results

Table 1 outlines the descriptive statistics for the study. A significant (t (175.91) = 2.65; p = .009; CI_{95} = (.10, 0.68), but small effect approaching the medium range (d = .39) existed between the cued and non-cued groups for transfer of the structural principle. The structural principle outcome variable was negatively skewed for the cued and non-cued groups (*ses* = - 5.51 and - 2.66, respectively).

In contrast, distribution of transfer scores for the optimal treatment method were relatively equivalent. However, no significant difference was found for cued and non-cued groups (t (190) = .874; p = .39; CI_{95} = (-0.14, 0.36) and an even smaller effect size (d = .13) was present. The optimal treatment method variable was also negatively skewed among the cued and non-cued groups (*ses* = -4.39, - 3.92, respectively).

Table 1. Mean Difference of Transfer Scores

Outcome Variable	**Cued Participants**	**Non-Cued Participants**	***t* Value**	***P* Value**	**Effect Size (*d*)**
Structural Principle	M = 2.30 SD = .89	M = 2.14 SD = .86	(175.91) 2.65	.009	.39
Treatment Method	M = 1.9 SD = 1.14	M = 2.03 SD = .90	(190) .874	.380	.13

A weak but significant Pearson Product-Moment correlation coefficient of r (190) = .34, $p < .001$ ($r^2 = .12$) was observed between the structural principle and treatment method variables, which persisted after post-hoc elimination of outliers (± 1.5 SD). Correlational analysis of the dependent variables (structural principle and optimal treatment method) and covariates (prior experience and demographics) did not reveal any significant relationships ($p = >.05$). Therefore, based on these findings, the covariates were assessed not to have had an impact on transfer outcomes, negating the need for ANCOVA analysis.

Discussion

Historically, students pursuing an allied health or medical degree have received the majority of their professional education and training based on the case method of instruction (Sage, 2003). However, findings of our current study, which are consistent with those in the cognitive literature (Gentner et al., 2003; Gentner & Colhoun, 2010; Novick & Holyoak, 1991; Shayo & Olfman, 2000), suggest multiple case examination with cueing to be a more effective pedagogical technique over singular or multiple case examination alone to improve learning transfer and problem solving among novice pre-professional healthcare undergraduates. Additionally, our findings support the underpinnings of case-based analogical reasoning with cueing for novice healthcare students; cueing students to look for structural relationships across multiple patient cases assists in identification of the cases shared structural principle(s), (b) builds schema that result in more effective problem-solving and (c) fosters learning transfer. Moreover, the results of the study also suggest that cued students may form a perception of applicability of their learning experience, thereby, improving transfer because they are aware the learning experience will help them solve a future goal or problem.

Multiple studies (Gentner et al., 2003; ; Holyoak & Koh, 1987; Shayo & Olfman, 2000) have affirmed comparison of relevant multiple case examples with cueing a powerful tool for promoting learning transfer and development of problem solving, but critics have questioned the ability of mock case-based analogical reasoning pedagogy to help prepare students to solve real-world problems. Seel (2006) argued that solution of complex real-world problems may not be teachable at all through a mock analogical reasoning process. He contended problems must be "experienced and dealt with using general intelligence and world knowledge" (p. 47). Moreover, critics may also point out that novices not only need similar prior experience to engage in successful analogical reasoning and transfer, but must also possess proficiency in the respective domain: albeit; without experience, no opportunity exists to even develop proficiency, let alone recall the experience for application. However, Gentner et al. (2003) showed that prior experience with a source analogue or domain—although helpful to engender analogical reasoning—is not absolutely necessary because multiple case examination with cueing supplants lack of prior experience within the domain and serves to fill relational gaps in individuals' experience, thereby, providing them a foundation upon which to compare and solve novel problems.

Even though skewness was present in our findings, we believe the skewness was a representation of the treatment intervention rather than a limitation in study design. According to Lomax (1988) a value of greater than 2.0 indicates a violation of assumption of normality to be investigated. However, violation of assumption of normality may only be problematic if the test or measure being used is norm-referenced, which was not the case with our experiment (Brown, 1997). Additionally, Tabachnick and Fidell (1996) noted large sample sizes are less prone to nonnormality and therefore variable transformations are not as imperative. Regardless, skewness was investigated to determine if one of the covariates in the study (e.g., prior experience) was the result. After exploratory and transformational analysis, normality of means could not be established. Therefore, the skewness present was deemed likely to be the result of the cueing intervention. However, there is a possibility an unknown confounding variable has not been identified.

Our findings for transfer of the structural principle affirm the value of using a case-based analogical reasoning process with cueing to improve transfer and problem solving in a pre-professional undergraduate novice population. Cued participants who demonstrated greater transfer of the structural principle likely did so because they were prompted to actively look for and compare the structural similarities between the heat-illness cases unlike non-cued participants who analyzed the cases separately. Across multiple studies by Cummins (1992), participants who engaged in active comparison of cases rather than analyzing them separately demonstrated a greater ability to organize and describe the cases in terms of their structure and surface similarity. Other researchers demonstrated when individuals use multiple examples for problem solving, they do not override their induced schema, but supplement and enhance existing schema for future problem solving (Novick & Holyoak, 1991). Another outcome from this process may be the development of a higher level of learner self-efficacy, derived from a perception that the learning experience is relevant for helping them solve future problems.

Shayo and Olfman (2000) demonstrated a significant improvement in transfer and self-efficacy among computer science undergraduates when exposed to multiple relevant rather than generic database case examples. Engendering learner self-efficacy when engaging in complex tasks is essential because it encourages the learner to persevere to attain their goal when cognitively challenged (Cummins, 1992), which typically occurs among novices when presented with unfamiliar tasks (Tuovinen, 1999). The possibility exists that participants who are exposed to relevant case examples identify them as applicable for solving future problems—their applicability serving as a cue—thereby increasing motivation to transfer their attributes and hence, improving self-efficacy because they feel they can use them to solve future problems (Bandura, 1982). In our study, cueing experimental group participants that comparison of the heat illness cases would help them solve a future patient case may have facilitated not only participants to identify the shared structural principle for solution—supplementing their schema—but also fostered a perception of applicability of the exercise for more effective problem solving.

Compared with the positive findings for transfer of the structural principle, the cueing intervention did not have a significant impact on transfer of the optimal treatment method to the target case. A simple explanation may exist for this finding. Novick (1988) has found when novices attempt to solve a problem they are likely to retrieve similar past experiences to form their solution procedure, even when cued to use a correct solution procedure that has been provided. Novices demonstrate a preference to retrieve, map and utilize knowledge based on prior experience and associated solution procedures despite being insufficient to solve the target problem because the surface attributes are more similar to the target problem (Gentner et al., 2003; Novick & Holyoak, 1991). Lacking a significant difference in our groups based on prior experience with the case content, the likelihood exists that the lack of a transfer effect of the optimal treatment method was the result of either how the cues or cases were constructed; cued participants may not have recognized the future utility of the optimal treatment method utilized in the heat-illness cases. That is, the written cue or solution of the hypothermic case may have been so simple and intuitive in nature (i.e., apply heat directly to the patient) that the cueing intervention had a negligible influence.

The observed association between the structural principle and optimal treatment method variables may have had an impact on how participants went about solving the target case. Regulation of core body temperature and application of either heat or cold share an inverse relationship, applying cold lowers core body temperature and heat raises it, which may have facilitated an understanding of how to treat the hypothermic patient in the target case.

So, if the process of multiple case examination with cueing is such a powerful tool for facilitating learning transfer, then why was a larger effect for cued and non-cued participants not evident in this study? The authors attribute the lack of robustness in effect between groups to possible limitations associated with the cueing intervention. One such limitation may have been how the cueing intervention was delivered.

In order to control variance in our study, we chose to deliver the cueing intervention through written instruction instead of guided verbal instruction, which has been shown to be effective in promoting transfer. Gentner et al. (2003) found undergraduate business students who received guided instruction (probing participants with questions related to their understanding of comparison cases for application to a test case) proposed more solutions and demonstrated better transfer of a business negotiation principle to solve a business problem than participants who received simple or no instruction. These results point to the value of providing students with real-time guidance and feedback to assist them in calibration of their thinking when engaged in a case-based analogical reasoning process. Even though paper-based cueing may ensure more consistent delivery of cases and their cues, the format does not provide learners' feedback on how the cases or the structural principle(s) might be interpreted or applied. The paper-based delivery format may have also caused cognitive overload of the participants.

When the capacity of working memory is limited or exceeded, cognitive overload occurs (Tuovinen & Sweller, 1999). The inability of our participants to reference the worked-cases and respective analyses when attempting to solve the target case may have unduly taxed their working memory, causing cognitive overload, which inhibited transfer and problem solving. Additionally, Waltz et al. (2000) found mapping of relational attributes between case examples requires more working memory. Cognitive load theory suggests that individuals have a limited short-term working memory capacity that can be overwhelmed with complex task requirements (Tuovinen & Sweller, 1999). Several studies have shown that when cognitive demand is high, transfer is impeded (Novick & Holyoak, 1991; Robins & Mayer, 1993; Tuovinen & Sweller, 1999). Three primary factors have been identified to increase cognitive demand during the analogical reasoning process: decreased time to solve problems (Novick, 1988), lack of explanation of the target solution procedure (Robins & Mayer, 1993), and use of non-worked cases (Tuovinen & Sweller, 1999). We believe that even though our participants were provided worked case examples with solutions and ample time to complete the problems, the lack of verbal explanation coupled with the need to remember the cases and analyses when attempting to solve the third case may have demanded a greater amount of working memory to process the structural attributes of the cases, thwarting a more positive transfer effect.

Regardless of the limitations in the present study, cued participants transferred the structural principle more than non-cued participants and solved the dissimilar patient case more effectively. Even though generalization of the study and its outcomes to other teaching methods (e.g., problem-based learning, web-based learning, etc.) and non-academic settings (e.g., workplace training) is limited because the study setting occurred in a traditional undergraduate academic classroom environment, clinically, the implications are significant.

In 2001, the Institute of Medicine (IOM), a committee of physicians and health policy experts charged to improve the health of the nation by the U.S. National Academy of Sciences, identified a gap in the area of education of healthcare practitioners as one of the reasons for medical error. We along with our other colleagues (Gentner & Colhoun, 2010; Hummel & Nadolski, 2002; Norman et al., 2007; Shine, 2002) believe that traditional instructional strategies such as single case examination are insufficient to enable students to transfer what they have learned in the classroom to address novel clinical problems they will face as future healthcare professionals (Shine, 2002; Weeks et al., 2001). With the gravity of how we instruct our future healthcare practitioners upon us, utilization of multiple case-based examination with cueing is an effective pedagogical approach to supplement and in some cases, replace the use of single case examination.

Additionally, the use of relevant worked patient cases in the formative years of development will assist educators in keeping cognitive load low and will provide students exemplars of best practice to build their schema foundation. By building a deep cognitive relational foundation for our future healthcare practitioners, they will be well-equipped with effective problem-solving skills that will enable them to keep pace with the ever expanding rate of medical knowledge and the clinical problems never encountered during their training.

Conclusion

The ability of medical practitioners to apply what they have learned to similar contexts is assumed, but they are also expected to be able to solve unfamiliar medical problems on the basis of their generalized training (Ericsson, 2004; Shine, 2002). However, medical educators and researchers have linked a lack of mental flexibility (Weeks, et al., 2000, 2001) and problem-solving ability (Ericsson, 2004; Norman et al., 2007; Shine, 2002) among students in medical curricula to traditional teaching methods such as single case examination, which may result in medical error (Shine, 2002).

The findings of our study are a first step towards addressing the medical error phenomenon and overall lack of transferability of classroom instruction to clinical practice. Two observations from our findings are particularly relevant based on the context of educating future healthcare practitioners. First, learning transfer and problem solving are improved with the use of a paper-based format that provides novel pre-professional healthcare students cues when examining multiple worked cases, a potentially useful pedagogical tool to engender novice learning for large class sizes.

Second, a paper-based format may not be as useful for teaching treatment approaches unless constructed in a manner that brings more depth to the application of their principle(s) or concept(s). Future research should explore how the pedagogical approach utilized in this study works over an extended period of time with allied health students, medical students and practicing clinicians. Additionally, studies should be conducted to determine what role and magnitude a perception of applicability of a case-based analogical reasoning learning experience plays in the motivation of individuals to transfer classroom learning to clinical practice.

CHAPTER IV

Making the Case for Case-Based Analogical Reasoning

The historical goal of teaching has been to foster the ability of students to transfer what they have learned from one context to another (McKeough, Lupart & Marini, 1995). Indeed, a primary goal of athletic training educators is ensuring that newly graduated athletic trainers possess the requisite knowledge and problem-solving skills to provide consistently high-quality care to their patients (Schellhase, 2008). The gravity of this goal has now fallen squarely on athletic training educators.

In 2004, the internship route to athletic training certification ended, and the Commission on Accreditation of Allied Health Education Programs mandated the national accreditation of athletic training educational programs. The standards imposed by this accreditation body required institutions and their respective programs to validate educational outcomes and improve accountability in order to protect the public from harm. Though similar to the medical school apprenticeship model, the athletic training internships that existed before 2004 lacked uniformity in quality of instruction from program to program (Schellhase, 2008). During his tenure in the mid-1990s as president of the National Athletic Trainers' Association (NATA), Dennis Miller had stated publicly that the quality of athletic training education was an ongoing problem: "Some things that have been coming up consistently loud and clear were problems with employment, problems with the quality of the education of the entry-level athletic trainer, problems with the clinical education of the entry-level athletic trainer..." (McMullan, 1996, p. 17).

Compounded by mounting concern among healthcare policy experts that medical error has become alarmingly widespread in the United States (Kohn, Corrigan & Donaldson, 2000), athletic training educators have ample reason to continue investigating, validating and implementing teaching techniques known to enhance the ability of students to transfer learning into correct action when under pressure in real-world situations. In 1999, the Institute of Medicine drew attention to reports that the number of deaths in the United States from medical errors ranged between 44,000 and 98,000 annually (Kohn et al., 2000). Further underscoring the problem, a 2003 article in the policy journal *Health Affairs* pointed out that from 1999 to 2003, one-fourth of adults had experienced a medical error (Sage, 2003).

Although the incidence of medical errors committed by students in athletic training education programs and among professional athletic trainers has not been well tracked, they may very well be the first to commit a medical error (Mitten, 1993). The professional athletic trainer is a "gate keeper" in the healthcare system and is often the first practitioner to care for a patient in the athletic environment. These circumstances require robust clinical decision-making skills (Schellhase, 2008), placing athletic trainers at increased risk for litigation (Mitten, 1993). Therefore, when viewed from any number of perspectives, incentives arise for investigating more effective ways to ensure students can transfer knowledge into correct action to serve patients effectively when under pressure.

A promising pedagogical approach for improving learning transfer among undergraduate pre-professionals is case-based analogical reasoning with instructor cueing (Gentner, Loewenstein & Thompson, 2003; Norman et al., 2007; Speicher & Kehrhahn, 2009; Speicher, Kehrhahn, Bell & Casa, 2010). Yet, Seel (2006) has argued that solution of complex real-world problems may not be teachable at all through a mock analogical reasoning process. He contended that problems must be "experienced and dealt with using general intelligence and world knowledge"(p. 47) However, multiple studies (Gentner, Loewenstein & Thompson, 2003; Norman et al., 2007; Speicher, et al., 2010), coupled with a body of cognitive research (Dunker & Lees, 1945; Gick & Holyoak, 1987; Holyoak & Koh, 1987; Hmelo-Silver, 2004; Hummel & Nadolski, 2002; Novick, 1988), have affirmed that comparison of multiple case examples with cueing is a powerful tool for promoting learning transfer and development of problem solving.

In this article, we provide athletic training educators and athletic training education program (ATEP) administrators with a rationale for implementing a case-based analogical reasoning pedagogical approach to improve learning transfer. We also give practical recommendations for implementing this approach to promote an ongoing effort to improve educators' ability to bridge the transfer gap between classroom and clinical settings to improve quality of patient care.

Case-Based Learning

A highly publicized legal case (Stringer v. Minnesota Vikings, 2005) involving an athletic trainer being on the frontline of the healthcare system involved the death in 2001 of Korey Stringer, a Minnesota Vikings offensive lineman. It was hot and humid the first day (July 30th) of preseason morning practice. Korey complained to the athletic training staff before practice of an upset stomach and was provided an antacid because one of the athletic trainers reported Korey commented he was anxious. Before the afternoon practice he was also provided Gatorade to consume because he was known to have a history of heat related problems. Forty-five minutes into the afternoon session he vomited twice resulting in his removal from practice by his coach and subsequent evaluation by one of the team's athletic trainers. Upon vomiting a third time, he was taken to a trailer on the sidelines and advised to consume more fluids and to "cool down and [to] take it easy" (Stringer v. Minnesota Vikings, p. 5), but was not examined by the medical staff present before he left on his own volition. However, medical notes from the team physician present in the trailer at the time noted Stringer "had an episode of heat exhaustion during afternoon training camp [and] …recovered without incident following rest and hydration"(Stringer v. Minnesota Vikings, p. 6).

The following day was also hot and humid and by 9:00am when practice started, the heat index was at 90. Korey's heat-related symptoms progressed, resulting in vomiting early in practice and then collapse towards the end. The athletic training staff summoned to evaluate him on the field reported that his skin appeared cool and moist and that he was uncooperative to their questioning, but was able to get up without assistance. He was then taken by one of the team's athletic trainers to an air-conditioned trailer to rest and after a period of time moved to the floor to lie down, where he slipped into unconsciousness. The athletic training staff applied cold packs and cold compresses to his body, but did not take his temperature. He remained unresponsive resulting in transport to the hospital. At the time of admission (12:35pm, July 31st) his core temperature was 108.8 degrees Fahrenheit. Korey died the next morning at 1:50am from organ failure as a result of heat stroke. During testimony, one of the athletic trainers commented on why the medical staff did not think Korey was suffering from heat illness even though he had a previous history of heat related problems and had demonstrated classic signs of a heat illness[21] over the course of the 2 days of training camp: "I thought there was a possibility [Stringer] could have just fainted. I thought that he could have had the possibility of a seizure, which would have—could have been done by an insect bite or some medication that he had taken or something"(Stringer v. Minnesota Vikings, p. 8).

Could Stringer's death have been prevented if the practitioners' had more effectively transferred their knowledge of heat illness and the pertinent treatment skills taught during their education to the field at the time of Stringer's health crisis? We may never know. But we do know that traditional instructional strategies, such as single case examination, are insufficient to enable students to transfer their classroom learning to real-life clinical situations (Weeks, Lyne, Mosely & Torrance, 2001) or to address novel clinical problems they will face as healthcare professionals (Shine, 2002).

Educators and researchers have long struggled to identify instructional methods to optimally foster transfer of learning. Over a century ago, Thorndike and Woodworth (1901) set the stage for learning transfer research by identifying that individuals more readily retrieve experiences that are similar in surface features, such as shape, color or context. But later work demonstrated that individuals value robust structural relationships (e.g., principles or concepts) more than surface features for problem solving (Dunker & Lees, 1945; Gentner & Markman, 1997; Holyoak & Koh, 1987). According to Gentner's structure-mapping theory (1983), a structural principle is a set of correspondences between examples or experiences. For example, a cell phone and two-way radio differ in surface features; however, both share the structural principle of being a tool used for communication. Once the shared principle has been identified, an individual can then utilize it to solve novel problems (Gentner, Loewenstein & Thompson, 2003).

Case-based analogical reasoning is a pedagogical technique that improves problem solving by assisting learners in identifying a common structural principle shared among multiple cases for solution of a future problem or case (Speicher & Kehrhahn, 2009). When cueing (i.e., providing hints) is coupled with the process, transfer of the structural principle to the target problem is enhanced further (Gentner, Loewenstein & Thompson; Holyoak & Koh, 1987; Norman et al., 2007; Speicher, et al., 2010). Nonetheless, the use of single patient cases persists in healthcare educational settings to promote transfer from the classroom to the clinical setting (Shine, 2002), including problem-based learning curricula (Hummel & Nadolski, 2002). This occurs despite the fact it has been well established that the practice is less effective than comparison of multiple cases accompanied by cueing (Gentner, Loewenstein & Thompson; Holyoak & Koh, 1987; Norman et al., 2007; Speicher, et al., 2010).

Learning and Neuroanatomy

Learning is based on neural connections in the brain being created and recreated through experience (Leamnson, 2000). According to Mathison (2010) the human brain (Figure 4) weighs approximately 3 pounds and contains 100 billion neurons and innumerable synapses that interconnect them (Edelman & Tononi, 2001). Even though each brain is similar in gross structure, the neural connections made from experience are unique for each individual (LeDoux, 2002). The plasticity of neural connections enables

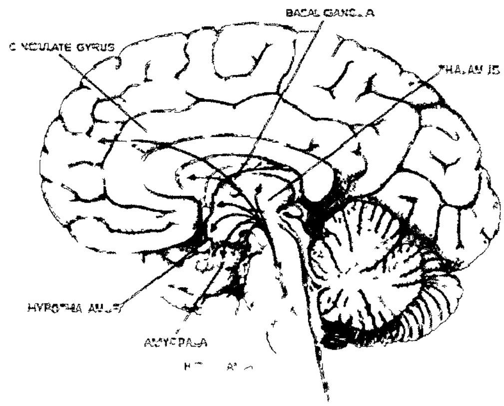

Figure 5. Gross Anatomy of the Brain

formation of individualized synaptic connections and neural groups that are extended, die or are modified on the basis of a lifetime of experiences (Edelman & Tononi, 2001).

In their neuronal group selection theory, Edelman and Tononi (2001) propose that we are born with a certain amount of hard-wiring for essential functions such as heart rate and respiration, however the majority of neurons and their synapses are unstructured and undeveloped. Neuronal connections, report the authors, are selectively constructed, remodeled and strengthened by experience to form neuronal network groups throughout the brain that map information from one to another, forming context-rich, specific memories that enable action. New neural connections are unstable at first, but can be strengthened through repetitive use (LeDoux, 2002). Simply stated, "neurons that fire together, wire together" (LeDoux, 2002, p. 29).

Consider the first time you navigated your way to a new job. At first, finding the route may have been difficult, but after many trips, the route becomes burned into memory, easing the commute. The ability to learn the most optimal route was not the result of only one factor or event but was instead the result of many, such as driving time, scenery, traffic patterns, perceived safety, etc. In addition, unexpected occurrences such as construction may have influenced the decision to modify the route over the course of learning the commute. On a basic level, the recognition of an ideal route and adaptation of the route over time to efficiently arrive at work is similar to the brain's ability to recognize patterns and adapt them to solve a problem or obtain a goal. Each time we attempt to remember and apply an experience, we reconstruct the experience, further burning it into our circuitry (Leamnson, 2000). David Kolb (1984) in his foundational text, *Experiential Learning: Experience as the Source of Learning and Development*, states "ideas are not fixed and immutable elements of thought but are formed and re-formed through experience" (p. 26). The ability to keep synaptic connectivity "alive," however, also depends on the initial strength of the stimulus.

Emotion and Memory

The memory of experiences associated with powerful emotions are more easily retrieved and retained for future use (Demasio, 2000; LeDoux, 2002). Because of the frontal lobes' connection with the limbic system (hippocampus, hypothalamus, amygdala), it is not surprising that learning is enhanced by emotion (Leamnson, 2000).

For example, most of us in the U.S. can recall vividly where we were on 9/11 when airplanes struck the World Trade Center's twin towers. The event, paired with a significant emotional/chemical response, has created a durable memory trace, making it unlikely the memory will be completely forgotten. When strong emotional responses are chemically coupled with an experience, neurons fired during the experience are imprinted strongly as well (Demasio, 2002). The chemical imprint results in less effort being needed to stimulate the associated neurons to recall the memory (Gelbard-Sagiv, Mukamel, Harel & Malach, 2008).

Imprinting or encoding memory for later recall requires the following neurochemical processes as articulated by LeDoux (2002). Voltage-gated channels at the postsynaptic junction are flooded with glutamate (an excitatory neurotransmitter) in the presence of a large stimulus. Glutamate binds to AMPA (α-amino-3-hydroxy-5-methyl-4-isoxazolepropionic acid) glutamate receptors to initiate a postsynaptic action potential to facilitate removal of magnesium from NMDA (*N*-methyl *D*-aspartate) glutamate receptors. Under low-stimulus conditions, glutamate receptors are blocked by the presence of magnesium, inhibiting calcium uptake. However, when the presynaptic cell delivers a large stimulus, uptake occurs at the postsynaptic NMDA receptors, resulting in kinase release in the cell body. The presence of kinases produces more AMPA receptors for glutamate binding, which produces an action potential along the postsynaptic nerve. Moreover, kinases alter the protein structure of the postsynaptic cell, allowing it to be more easily stimulated to produce an action potential from subsequent weak stimuli.

Therefore, even seeing a plane on the tarmac may provide enough stimuli to ignite the previous memory of 9/11 for some people. A weaker stimulus can promote retrieval of an initial memory encoding and its associated emotional response because the changes in the nerve cell allow neuronal activity in the postsynaptic cell to persist and to be more easily stimulated by surrounding presynaptic nerve cells that elicit weaker stimuli, a mechanism known as (LTP) long-term potentiation (Gelbard-Sagiv, et al., 2008). Engendering LTP is critical for novice healthcare students because novices have traditionally exhibited difficulty in retrieving prior learning experiences for novel problem solving (Holyoak & Koh, 1987; Novick & Holyoak, 1991). Pairing powerful stimulus cues with an analogical learning experience enables better recall and mapping of structural similarities between past and present experiences for successful novel problem solving (Gentner, Loewenstein & Thompson, 2003; Norman, et al., 2007; Speicher & Kehrhahn, 2009; Speicher, et al., 2010).

In sum, the ability to learn is influenced by the multiplication of dendrite and axonal branches to other neurons over time, sparked by changes in emotion from experiences we incur. The resulting neurochemical "wiring" process promotes stability and persistence of synaptic connections for future problem solving.

Implicit Learning

The experiences we accumulate over our lifetime result in either explicit or implicit (tacit) learning (Reber, 1989). However, researchers posit that more than 90% of learning is tacit or unconscious in nature (Clark & Ellen, 2006). With this in mind, it behooves the educator to understand the cognitive processes responsible for learning, and, in particular, how implicit learning and tacit knowledge can be optimized. Learning transfer through case-based analogical reasoning with cueing is such a tool.

The case-comparison process optimizes learning transfer by means of the basal-ganglia system's[2] preference for identifying structural rules and patterns shared among experiences (Edelman & Tononi, 2001). Consider solving a crossword puzzle. Individuals follow the structure and usually become better at solving crossword puzzles, partly because the mind unconsciously recognizes the puzzle's structural pattern of rules, which facilitates applying the solvers' knowledge more efficiently. Simply, individuals acquire the implicit rules required to successfully work the crossword puzzle even though they may not be able to explicitly articulate the process. Reber (1989) has reported that tacit knowledge is always more robust and complex than the explicit knowledge individuals are able to articulate. For example, when participants in a study by Speicher et al. (2010) were asked how they arrived at their solutions to a target case after comparing two structurally similar cases they voiced difficulty in communicating their tacit knowledge: *"I don't know why I am thinking that... ." "Well, I don't know... ."* Testimony of the athletic trainer in the Stringer case suggests that he too was unsure how he had formed his seizure diagnosis.

The Speicher et al. (2010) study was conducted by the authors. The sample (N = 198) was composed of pre-professional undergraduate athletic training, exercise science, medicine and physical therapy students. Participants compared two worked patient cases involving heat illness for solution of a third hypothermic case. Participant solutions for the target case were evaluated for the extent of transfer of the heat-illness case's structural principle (thermoregulation of core body temperature) and optimal treatment

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[2] The basal ganglia is a set of nuclei that receives connections from the cortex, which project to the thalamus and back to the cortex. The role of this structure is to plan and execute motor and cognitive acts.

method (direct full-body treatment technique). Additionally, semi-formal interviews (n = 6) were conducted to assess the thinking process students used to solve the target case. Cued over non-cued participants demonstrated significantly more transfer ($p = .009$; $d = .39$). Cued participants used the implicit structural principle embedded in the heat illness cases better than non-cued participants for solution of the target case, a finding consistent in the cognitive literature (Holyoak & Koh, 1987; Gentner et al., 2003). However, no statistical difference ($p = .38$; $d = .13$) in transfer of the optimal treatment method was evident for the groups.

When exposing learners to tacit structural patterns to improve learning transfer, several factors impact structural principle acquisition and application. In Reber and Millward's (1965) seminal study of grammar processing, participants exposed to grammar strings governed by ordered implicit rules demonstrated better processing and memory of the grammar strings, enabling them to differentiate them from strings lacking the same rules. However, Reber (1989) observed that the implicit structure in the stimulus must be complex enough to avoid conscious effort from breaking the "code." Why? When the structure is easily identifiable, learners often invoke their prior experience, which often results in use of incorrect solution procedures (Novick & Holyoak, 1991; Reber, 1989). Perhaps this is why there was not a greater treatment effect for the method employed by Speicher et al. (2010) to promote participants' transfer of an underlying structural pattern across cases—the embedded treatment method may have been just too simple and recognizable.

Several interviewees involved in the Speicher et al. (2010) study, when queried about the strategy they used for the third target case, which depicted a hypothermic patient, commented: *"Just from my own knowledge... ." "Kind of like common knowledge, if he is pale, blue, and shivering, he is really cold from what I know... ." "...personally I know 45 degrees in water is pretty cold... ."* Several other studies (Novick, 1988; Novick & Holyoak, 1991; Reber, 1989) have reported that when novices are not able to recognize a structural principle for solution of a target problem, they will use incorrect solution strategies based on their prior experience. These observations point to the vital nature of appropriate and robust case and cue construction. In order for learners' to identify imbibed structural patterns for successful problem solving, salient (Shayo & Olfman, 2000) and explicit cues (Reber, 1989) must be present to assist learners to find the patterns, particularly for novices (Novick, 1988).

The process of analogical reasoning capitalizes on the brain's preference to use tacit structural patterns for problem solving (Reber, 1989). However, novices demonstrate a preference for relying on surface features first, whereas experts primarily rely on structural features (Chi, Feltovich & Glaser, 1981). Even though surface features facilitate memory recall, structural principles are more effective for problem solving (Holyoak & Koh, 1987). Novices tend to rely on the surface features of an experience to solve problems (e.g., a sweaty appearance) because they have had less opportunity to form structural relationships among experiences over time (Novick, 1988). Perhaps the athletic trainer in the Stringer case had very little experience with heat stroke cases. This may have led to a reliance on superficial patient symptoms that resulted in the formation of an incorrect diagnosis and treatment plan. Therefore, for novices to execute successful novel problem solving, they must build a repertoire of similar experiences over time. While expanding their "cognitive tool set," they must be cued to look for the structural principles, patterns or relationships that exist between and among disparate cases. Such exposure increases implicit knowledge so it can be applied effectively to dissimilar patient cases when they arise. To optimize this process, students need to retrieve, map (compare) and abstract or adapt their experiences to a new problem (Gentner & Markman, 1987).

The hippocampus has shown to play a significant role in retrieving, mapping, and abstracting processes (Gelbard-Sagiv, et al., 2008; LeDoux, 2002). Edelman and Tononi (2001) have reported that the hippocampus[3] bundles experiences together in categories or episodes known as schema that serve as a file repository for our memories. Reliance on hippocampal neurons for memory retrieval has been well established in animal studies (O'Reilly & Rudy, 2001). Gelbard-Sagiv et al. (2008) have also reported similar results in a human population. The authors measured neuronal patterns in patients with pharmacologically intractable epilepsy by implanting electrodes in selected brain structures during and after video clip viewing of famous people, characters and animals engaged in activity. When asked to recall the clips, a significant increase in hippocampal and entorhinal[4] neuronal unit activity occured in contrast to frontal cortex activity, and the neuronal firing sequence exhibited at the start of video viewing was replicated during recall of the videos. Animal studies (O'Reilly & Rudy, 2001; Rudy & Barrientos & O'Reilly, 2002) also have demonstrated that neuronal firing patterns present during

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[3] The hippocampus located in the medial temporal lobe serves to consolidate short-term memory into long-term memory via the cerebral cortex.
[4] The entorhinal cortex (EC) also located in the medial temporal lobe is the connective pathway from the hippocampus to the cortex. The EC works in concert with the hippocampus to form memories, but its neurons are selective as to direction.

learning can be reactivated with both free recall *and* cueing. These observations affirm the role of the hippocampus in memory encoding and also signify the potential role that cueing may play in memory retrieval. However, the hippocampal system's role in promoting the transfer of structural principles for problem solving depends upon repeated communication with the cortical system over time (O'Reilly & Rudy, 2001).

When learners are motivated to compare experiences, associations or structural links known as *conjunctive representations* emerge (O'Reilly & Rudy, 2001). According to O'Reilly and Rudy (2001) conjunctive representations comprise both the structural and surface features common among experiences. For example, experience with multiple sweaty patients exercising in a high heat index progressively may form an association among these variables, implicitly connoting to the learner that a rise in core body temperature is the inevitable outcome. Unlike the hippocampus, which has a bias to quickly bind together and categorize surface features, such as a sweaty appearance, heat and humidity, the anterior cingulate cortex, which is located in the lower frontal aspect of the brain, maps multiple schema attributes over time among a variety of cortical appendages, such as the hippocampus, basal ganglia, and cerebellum (Edelman & Tononi, 2001; O'Reilly & Rudy, 2001). It is this experientially based mapping process that forms the structural relations so important to constructing mental models for problem solving (O'Reilly & Rudy, 2001).

Seel defines a mental model as "inventions of the mind that represent, organize, and restructure domain-specific knowledge" (2006, p. 408). The cognitive scaffolding and reorganization process that occurs over time to form a mental model assists learners' in solving problems because they contain not only common surface features of experiences shown to aid in retrieval of schemas (Gentner & Markman, 1997), but more importantly, contain structural principles and solution strategies that can be used for novel problem solving (Holyoak & Koh, 1987). Augmenting Steel's definition of mental models, Eckert and Bell (2005) observed that such models also convey to the learner how to act upon the embedded knowledge and conceptions for problem solving.

The prefrontal cortex is primarily responsible for enabling learners to forecast or abstract their conceptions of mental-model utility for problem solving (O'Reilly & Rudy, 2001). However, according to O'Reilly & Rudy (2001) it takes multiple experiences over time for the cortical system to form conjunctive representations (structural principles) to enable extension of consciousness for future problem solving. Newly minted athletic trainers may not have had the time or necessary experiences to develop conjunctive representations before being faced with their first heat stroke patient. Fortunately, a lack of experience in a particular domain can be supplemented through a pedagogy utilizing case-based analogical reasoning with cueing (Gentner, et al., 2003).

Novices typically need help not only with building mental models of a specific domain, e.g., heat illness, but also with retrieving and remembering the domain knowledge. A case-based analogical reasoning process coupled with cueing assists with accomplishing this lofty task in three primary ways. Foremost, the process of comparing multiple cases and uncovering their common structural principle builds the learner's schema to aid problem-solving ability (Gentner, et al., 2003; Norman et al., 2007). The cases serve as exemplar examples to supplant lack of experience in a respective domain. Several studies (Gentner et al., 2003; Norman et al., 2007; Shayo & Olfmann, 2000) have reported that exposing novices to comparison of multiple case examples for the purpose of applying their shared structural principle assists in the development of quality schema in spite of a lack of real-life experience.

Second, cues associated with cases may assist the learner to retrieve past memories from their hippocampus (Gelbard-Sagiv, et al., 2008; O'Reilly & Rudy, 2001), alert them to identify the structural principle(s) shared in the cases (Reber & Millward, 1965) and may serve as triggers for future recall in solving problems (Novick & Holyoak, 1991). Clark and Harrelson (2002) have asserted that successful transfer depends on the encoding of cues with an experience and is one of the most important factors for later recall of experience. Therefore, a primary goal of the educator should be coupling cues with a learning experience to foster learning transfer. Moreover, when the cue and learning experience invokes a change in emotion, the experience engenders hippocampal encoding for future recall (Demasio, 2000).

Third, the pedagogical process creates new neural connections between memories and reinforces existing neural relations or connectivity between existing memories (Leamnson, 2000; LeDoux, 2002). The reasoning process forces the hippocampus and cortex to disassociate between surface and structural attributes scaffolded onto existing memories (Seel, 2006). Cues encoded with memories serve as a "file tab" for the memory, enabling more efficient retrieval when needed (Demasio, 2000). The ability to efficiently retrieve existing schema for problem solving among novices reduces cognitive load and improves transfer of learning (Clark & Harrelson, 2002; Novick & Holyoak, 1991). The dynamic neural process of recreating a mental scene from either prior experience or exemplar cases fosters the ability of the learner to extend the scene and its solutions to the future for novel problem solving. In this way, the perception of applicability of the learning experience may foster learning transfer (Speicher & Kehrhahn, 2009).

Edelman and Tononi (2001) posited that when individuals recreate a mental scene from their past experiences (the "Remembered Present"), it stabilizes and modifies neural networks for future planning. They identify three requirements for creation of a "Remembered Present": categorization of perceptual experiences into schema; formation of schema into concepts; and abstraction of the concepts. The analogical reasoning process with cueing is an ideal pedagogical technique to facilitate creation of a remembered present because the instructional technique promotes memory retrieval, mapping of past and current experience, and abstraction for application to a problem. Additionally, cueing during the case-based analogical reasoning process may serve to cognitively tag the structural principle derived from the comparison of multiple cases, implicitly or explicitly alerting the learner of their presence for use and later recall.

Lesson Design

When setting out to design and implement a case-based analogical reasoning lesson in the classroom environment to improve learning transfer, several factors are important to consider. As depicted in Figure 6, the instructor must construct structurally sound patient cases that are factually valid and have pragmatic relevance to the student. The decision of whether to use worked patient cases will depend on the level of the students' prior experience with the content. A worked case provides a solution to the case, which is recommended if students have limited or no experience with a particular domain. After cases have been constructed, the instructor has a basis from which to construct the cues or prompts associated with the cases to yield desired learning outcomes. Depending upon class size and resources available, the instructor can use a written or oral method to deliver the cases and cues. Regardless of presentation format, cues should explicitly guide students in what to search for when assessing the cases and how to use their observations to solve a target problem. The target problem can be related or unrelated to the comparison cases but should be solvable from the structural principles or concepts gained from the case comparison process.

Case Construction

As recommended by Gentner and Collhouhn (2010) when cases are used for analogical comparison, they should be structurally sound, factually valid and have pragmatic relevance. However, before building multiple patient cases for comparison or the target case for solution, the instructor must decide which concepts or principles the student should acquire from the case-comparison process that could be applied as a solution. After identifying the structural principle(s), it must be embedded within the cases without explicitly revealing the principle(s) to the learner. Not revealing the structural principle is important because when the brain works to identify tacit structural patterns (e.g., thermoregulation) students are more likely to apply those patterns to solve novel problems than when focused on explicit principles (Reber & Millward, 1965) or surface features such as skin appearance (Gentner, Loewenstein & Thompson, 2003).

Patient cases will and should contain surface features such as patient signs and symptoms, but their attributes should *assist* students in identifying a structural principle rather than revealing it explicitly. For example, as seen in Figure 2, both comparison cases reveal to the student a high patient temperature, but do not explicitly uncover the implicit structural principle of thermoregulation of core body temperature used for effective treatment.

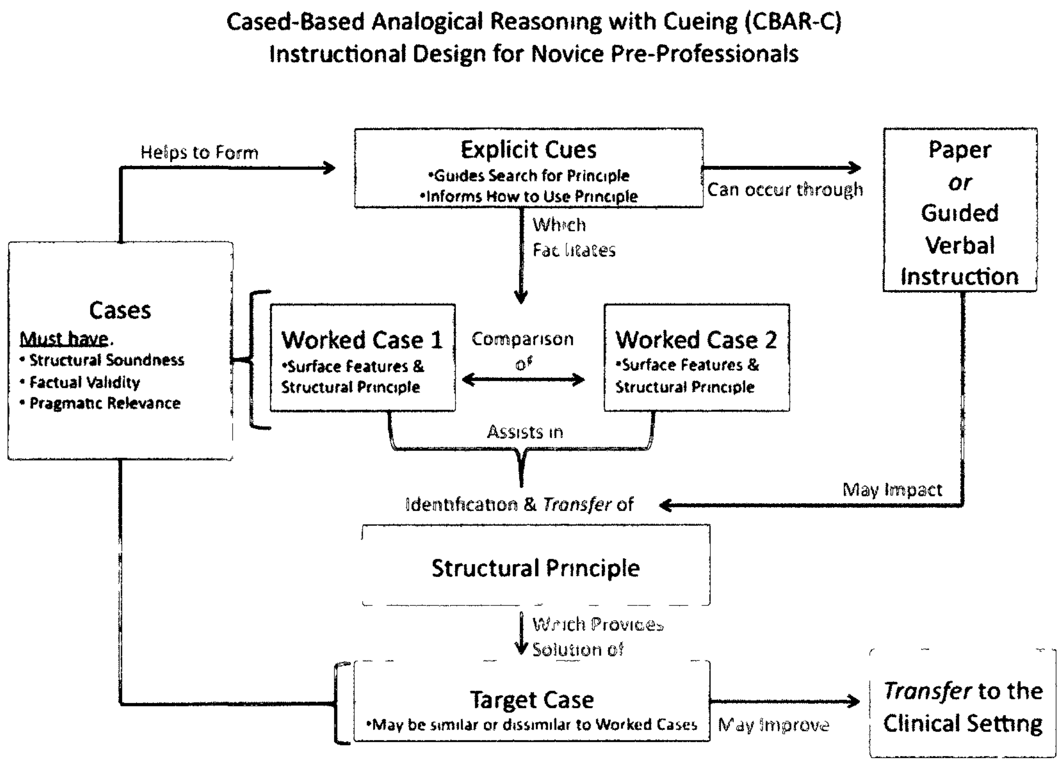

Figure 6. Case-Based Analogical Reasoning with Cueing Lesson Design

Patient case examples, however, do not have to be similar in nature as illustrated by the two comparison cases. In fact, dissimilar cases avoid the likelihood of students focusing on shared surface characteristics that are irrelevant to solving the problem (Gentner & Markman, 1997; Novick & Holyoak, 1991). For example, when comparing apples and pears, their surface features are dissimilar, but both share a core that is essential for growth and reproduction. On the other hand, if prompted to identify how a red apple and a green apple are similar, the learner would likely focus on surface characteristics—the similarity in size and shape, thereby missing the structural relationship both share, the core.

Even though patient cases may be dissimilar on the surface, they must share a structural principle that students can transfer to effectively solve a novel patient case problem (Gentner & Markman, 1997, Norman et al., 2007). When engaging novices in a case-based analogical reasoning lesson, worked patient cases (cases with solutions) should be used to optimally facilitate students in identifying structural principles over surface elements (Gentner & Colhoun, 2010). Worked cases can serve as exemplars of best practice for novice students, which not only builds their schema in a particular domain, but can also reduce the cognitive load they may experience during the case comparison process (Shayo & Olfman, 2000)' Cognitive overload results in a decreased capacity to learn and engage in successful problem solving due to the limited capacity of working memory (Tuovinen & Sweller, 1999). Novices have been shown to exhibit cognitive overload when processing unknown complex material (Novick & Holyoak, 1991; Tuovinen & Sweller, 1999). If novices do not have the schema present to process the elements of a case, they will have to process each element individually, resulting in high cognitive overload (Tuovinen & Sweller, 1999). Additionally, worked case examples are a form of task-valid cueing that provides rich contextual information to engender the construction of mental models (Hummel & Nadolski, 2002). Worked cases can free up working memory and reduce cognitive load (Tuovinen & Sweller, 1999), allowing learners to focus on relevant information and solutions for effective problem solving (Hummel & Nadolski, 2002). Solutions provided by worked cases supplant novice students' lack of experience with the examined domain, which may assist them in seeing the applicability of the case and solutions for future application.

Pragmatic Relevance

If learners perceive the patient cases as factually valid and relevant to their professional training and practice, transfer of learning from the lesson is more likely (Speicher & Kehrhahn, 2009). Shayo and Olfman (2000) reported a significant improvement in transfer and self-efficacy among computer science undergraduates after they had been exposed to multiple relevant rather than generic database case examples. Engendering learner self-efficacy when engaging in complex tasks is essential because it encourages the learner to persevere in attaining their goal when challenged cognitively (Bandura, 1982), which typically occurs among novices when presented with unfamiliar tasks (Tuovinen & Sweller, 1999). It may be that learners who are exposed to relevant case examples identify them as applicable for solving future problems—their applicability serving as a cue. In appreciating applicability of cases, learners may experience an increase in motivation to transfer case attributes and, hence, an increase in self-efficacy results because they feel they can use them to solve future problems.

At some time, we have all dissociated ourselves mentally from a learning experience because we either felt the information provided was inaccurate or not applicable for either solution of a problem or attainment of a personal or professional goal. Yelon, Sheppard, Sleight & Ford (2004) found that, among 73 physicians in a medical education teaching fellowship, the process of determining the applicability of a teaching technique for potential transfer rested heavily on the learner's identification and mapping of the technique to their schemas. The end result of the teaching fellows' mapping process assisted them in identifying the utility of their learning experiences during the fellowship training for accomplishing a future goal or solving a problem.

Novices, however, do not typically possess a rich base of experience to make an applicability judgment, nor do they often recognize the applicability of a current experience for future application (Novick & Holyoak, 1991). Speicher and Kerhrahn (2009) posited that the cueing an instructor provides during the case-based analogical reasoning process is not only central to helping students identify the applicability of their current learning experience for current and future use but also assists them in identifying the cases structural principle (Figure 1).

Cue Construction

Once learning outcomes have been set and cases constructed, the instructor should develop cues to guide students in identifying and using the embedded structural principle in the comparison cases for solution of a novel third target patient case. Inherently, implicit cues are built into the worked cases, such as signs and symptoms, as well as the handling of the cases. Researchers (Novick & Holyoak, 1991; Reber & Millward, 1965) have reported that if the structural principle is easily identified or provided, transfer and problem solving is compromised. To avoid compromising transfer, cueing can be provided at multiple points and in varied formats in an implicit manner during the analogical reasoning process to encourage identification and transfer of the shared structural principle for successful problem solving.

Speicher et al. (2010) used a paper-based, written format to deliver cues during comparison of the worked patient cases and other researchers (Gentner, Loewenstein & Thompson, 2003) have successfully used an oral delivery method. Providing cases and their cues on paper provides a standardized method of delivery to large student groups. In addition, formatting a written case description on the same sheet of paper is a form of cueing recommended by Gentner et al. (2003) to promote case comparison, as seen in Figure 3. In such a configuration, the authors speculate that the brain may gravitate more towards comparing the cases, in contrast to when they are presented on separate sheets. Paper-based formatting of case descriptions may also free up students' working memory because they are not required to remember the cases or cues. Moreover, freeing working memory may decrease cognitive load, contributing to improved transfer (Tuovinen & Sweller, 1999). Oral delivery, on the other hand, provides the student with an opportunity to affirm their understanding of the cue and the cases through feedback from the instructor. However, orally responding to multiple students in a large class may prove time-consuming for the instructor and introduce variability for the researcher that may be hard to control.

Discussion

Composition of pragmatically relevant worked cases and explicit cues to enable identification of structural principles for novel problem solving is essential to promote transfer for the novice pre-professional when engaging in a case-based analogical reasoning learning experience. The target patient case presented for solution also should possess directive cues to promote learners to transfer the structural principle gained from the case-comparison process (Figure 4). In the study by Speicher et al. (2010) the authors ascertained that the cues they constructed for the target case may not have been explicit or directive enough. For example, asking students to apply what they have learned may have been too vague. Instead, the authors recommend making the cue more explicit. Ask participants to identify a principle or solution strategy common among the comparison cases for application to the target case. Rather than participants warming the hypothermic patient in the target case with a warm direct full-body heating technique to raise core temperature, Speicher et al. (2010) found participants relied on their prior experience in forming an approach for treating the hypothermic patient in the target case. Participants remarked: "*He might also want to get up and move around in order to circulate the blood flow in his body… .*" "*You should immediately take his pulse, body temperature and blood pressure to get a better understanding of what the problem is. His body may have gone into shock due to the cold water… .*"

These interview findings revealed insufficiency with not only construction of the cues, but also possibly the target case. First, the cues utilized with the target case were not directive enough to promote participants to identify and transfer the comparison cases' treatment method and, secondly, the case itself may have been too simple in nature, leading participants to use their prior experience rather than the schema the researchers intended them to form from the case-comparison process.

Therefore, solution of a target case should not be solvable from prior or common experience alone. Rather, cues should be directive enough to prompt learners to transfer the principle desired by the instructor. To accomplish this goal, the cue in the target case in figure 4. used by Speicher et al. (2010) could be rewritten as follows: "*Taking into consideration the treatment methods used in the two previous cases, how could they be used now to treat this patient?*" This cue directs learners to actively compare the worked cases and abstract the treatment methods to the target case without explicitly identifying the optimal treatment approach used in the worked cases.

Novick and Holyoak (1991) have found novices typically do not engage in active analogical comparison unless cued to do so. However, in the study by Speicher et al. (2010) cued participants may have differed significantly from non-cued participants in regard to transference of the thermoregulation principle to the target case because they used pre-cueing with the comparison cases. As seen in figure 3., cued participants were pre-cued that comparing the worked cases would guide them toward a solution for a future case. The pre-cue may have alerted their brains to seek the structural relationship or solution embedded in the worked cases, and so they innately perceived the applicability of the exercise, highly motivating them to transfer the thermoregulation principle to the hypothermic target case. In a classic analogical reasoning study by Gick and Holyoak (1983), when participants were pre-cued or provided with a hint that comparing the two case examples would help them solve a future problem, 80% solved the target problem correctly versus 30% who also had knowledge of the examples but received no hint. Among participants who received the case example alone but no comparison examples or hints, only 10% solved the problem correctly. These findings affirm the essential nature of providing directive and explicit pre-cueing when engaging learners in an analogical reasoning process in order to guide the student to transfer his or her learning to solve novel problems effectively.

Case-based analogical reasoning with cueing is a pedagogical approach that can improve transfer of structural principles to enable solving novel problems and may aid in decreasing the occurrence of medical error by facilitating practitioners' ability to recall critical learning principles more easily when faced with novel real-world problems. Future studies should examine whether transfer of treatment methods can also be improved in a similar way.

Practical Implications

Practical application of case-based analogical reasoning pedagogy exists any time case examples are used in curricula to foster transfer of learning. Since abolishing the internship route to athletic trainer certification, the dichotomous nature of classroom-based education and hands-on clinical education has been magnified, creating a greater imperative today for athletic training educators to foster effective transfer of traditional classroom learning to the clinical practice setting—a challenging task. Prior to implementation of the new accreditation standards, the predominance of athletic training students' learning occurred through treatment of multiple patients in the clinical setting. Therefore, use of a case-based analogical reasoning process with cueing in the classroom setting may help to both supplant students' lack of experience with patients in the clinical setting and foster transfer of essential principles or best practices correctly to the patient population. Had the athletic trainers in the Stringer case been educated with this pedagogy, they might have learned the critical concept of regulating core temperature to prevent and treat heat illness, and might have been able to retrieve it from memory and apply it to the situation to prevent the player's death. Ironically, in light of the new accreditation standards, using analogical reasoning in a *clinical* environment may be even more powerful in promoting problem-solving skills and their transfer.

Unbeknownst to many athletic training clinical instructors, they may already be employing a case-based analogical reasoning process with cueing. Many of us have often prompted our students to compare one patient case to the other (e.g., multiple knee reconstructions) to enable students to identify a pattern in both presentation and treatment approach. However, the intent to do so may or may not have been purposeful. By encouraging students to engage in an analogical reasoning process across several patient cases in order to identify common principles shared among them for novel problem solving, students' schema quality and problem-solving capability should improve in contrast to when they are examining only one patient case at a time.

Moreover, if the clinical instructor can actively involve students in patient case situations that may invoke emotion, students will be more likely to remember the learning experience in the future. In addition, the clinical instructor can reinforce and strengthen transfer to and from the classroom and clinical setting by prompting students to use and compare their clinical experiences with their classroom learning. However, the clinical instructor must actively cue novice students to engage in the analogical reasoning process and apply it to a novel problem; otherwise students are less likely to do so, which may result in delayed development of their schema and mental models.

Problem-based learning (PBL) has traditionally attempted to develop the critical thinking skills needed in the clinical environment; typically only one case is used and often worked cases are not provided to novice learners. The overarching goal is for students to use their prior knowledge to solve the presented case or to discover new knowledge through both individual and group research (Hmelo-Silver, 2004). Based on the findings of Speicher et al. (2010) and those in the cognitive literature (Dunker &

Lees, 1945; Gick & Holyoak, 1983; Gentner & Markman, 1997; Holyoak & Koh, 1987; Hummel & Nadolski, 2002; Novick, 1988), the traditional PBL approach of singular case examination may not be effective in promoting either encoding of lessons learned from the case examination process or transfer to the clinical setting. Therefore, we advocate a case-based analogical reasoning process with cueing be used to maximize transfer of learning within the PBL curriculum.

Conclusion

The occurrence of medical error is inevitable. However, profession-wide, it can be better controlled with sound pedagogical approaches in the classroom and clinical practice settings. Through utilization of a case-based analogical reasoning approach with cueing, students' transfer of principles learned through this teaching method will improve their problem-solving ability, which will facilitate both recall of their learning and solution of novel clinical problems (Gentner et al., 2003; Norman et al., 2007; Speicher et al., 2010).

With the emergence of research demonstrating the power of multiple patient case examination with cueing to foster learning transfer, the traditional practice of singular patient case examination both in and outside the classroom may soon be passé. However, much work remains to be done to examine the effectiveness of various delivery methods of cases and cues as well as their utilization in a problem-based learning and clinical practice setting.

CHAPTER V

Conclusion

Eliminating medical error is inevitable, but it can be limited (Al-Assaf, Bumpus, Carter & Dixon, 2003). One way to limit error is effective education of health care students and professionals. The three papers presented begin to address the medical error phenomenon and overall lack of transferability of classroom instruction to clinical practice. The second paper's findings supported the author's proposition in the first that cueing is an essential instructional intervention to promote transfer of structural principles for effective problem solving. Building off the first and second paper, the third proposes modifications to the method of delivery of cases and cues used in a case-based analogical reasoning process.

Significant work though still needs to be undertaken to examine how best to design and deliver this type of curricular approach with pre-professional healthcare students. Although, if health care educators understand the factors which impact the formation of a perception of applicability of a learning experience, how the brain learns when presented multiple patient cases and instructional methods by which to facilitate the acquisition and transfer of structural principles to solve novel clinical problems—learning transfer from the classroom to the clinical environment may be improved. If transfer can be improved, the rate of medical error rampant in our healthcare system has the propensity to be reduced.

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APPENDIX A

Demographic and Prior Experience Survey (DPES)

Demographic Information

Please answer the following questions:

How old are you? _____

What is your gender? ____ Male ____ Female

What geographic location have you spent the most of your life?
- € Northeast
- € Southeast
- € Midwest
- € Northwest
- € Southwest
- € Other:________________________________

What is your Race? Select one or more of the categories listed:
- € American Indian or Alaska Native
- € Asian
- € Black or African American
- € Native Hawaiian or Other Pacific Islander
- € White
- € Some Other Race: ___________________

Prior Experience Information

Circle either Yes or No for each question:

Yes / No	Have you ever had a heat illness (e.g., heat exhaustion, heat stroke)?
Yes / No	Have you ever had a cold illness (e.g., hypothermia, frostbite)?
Yes / No	Have you ever received formal instruction on heat or cold illnesses?
Yes / No	Have you ever treated an individual with a heat or cold illness?
Yes / No	Have you ever observed an individual who has experienced a heat or cold illness?
Yes / No	Have you ever read any materials about heat or cold illnesses?

APPENDIX B

Learning Transfer Assessment Instrument (LTAI)

Rate separately, the amount of structural similarity of the solution principle and warming method provided by the subject for the target case to that of the inherent optimal solution principle in the base cases, which is thermoregulation of core body temperature through application of a direct full body heating technique.

Amount of Structural Similarity Present in Target Case Solution		
0	Not at all	Example: *The individual should be rushed to the hospital.* Thermoregulation principle and heating technique is NOT mentioned.
1	To a small extent	Example: *They need to get warm again by getting out of the whirlpool.* Thermoregulation principle present, but vague and patient centered. Heating technique is passive and patient centered.
2	To some extent	Example: W*arm the body by placing blankets over the body.* Thermoregulation principle present, vague, but clinician centered. Heating technique is direct but does is NOT applied full body.
3	To a great extent	Example: *Raise body temperature by wrapping individual with warm blankets.* Thermoregulation principle is explicitly present and is clinician centered. Heating technique is direct and applied to the full body and also involves a heating source (e.g., warm blankets).

APPENDIX C

Copyright Approval

The American Scholars Press Inc.

To Tim Speicher, PhD(c), ATC, CSCS
Clinical Coordinator
Director of Graduate Research
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Dear Author, Dr Tim Speicher,

The International Forum of Teaching and Studies has granted permission for Dr Tim Speicher, PhD(c), ATC, CSCS to reprint of his Perception of Applicability Model from his article published in the International Forum of Teaching and Studies Speicher, T E , & Kehrhahn, M (2009) Analogical reasoning A process for fostering transfer of learning from the classroom to the clinical practice setting International Forum of Teaching and Studies, 5 (2) 52-58

He plans to use the figure for submissions to the Journal of Academic Medicine, Journal of Athletic Training Education and also for his dissertation at the University of Connecticut

Sincerely,

Editors
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APPENDIX D

Information Sheet for Participation in a Research Study

University of Connecticut

Principal Investigator: Marijke Kehrhahn, PhD
Student Investigator: Tim Speicher
Study Title: Analogical reasoning: A process for fostering learning transfer from the classroom to clinical practice
Sponsor: Sacred Heart University

Introduction
You are invited to participate in this research study, which will examine your reading comprehension of cases involving patient care. Participation in the study is voluntary and confidential. Completion of the study should take no more than 30-40 minutes. You are a candidate for participation in this study if you are a first year athletic training student seeking future or continued enrollment in a Connecticut athletic training education program You must be 18 years or older

Why is this study being done?
This study will examine your reading comprehension of patient cases in order to determine effective teaching strategies educators can use to improve student learning.

What are the study procedures? What will I be asked to do?
You will receive cases involving patient care to read and interpret After interpretation of the cases, you will answer some questions about another patient case. Once you have completed your interpretation of the cases, you may be invited to participate in a five to ten minute taped interview in order to examine your comprehension of the cases in further detail Once you have completed the interpretation of the cases and/or the taped interview, you will be asked to complete a questionnaire to tell us a little bit about yourself.

Some research requires that the full purpose of the study not be explained before you participate in order not to bias your responses to the study, which is the case in this study. However, we will give you a full explanation as soon as you complete the study.

What are the risks or inconveniences of the study?
There are no known risks associated with this study

What are the benefits of the study?
You may directly benefit from participation in the study by gaining knowledge of patient care. However, indirectly, the findings from the study may provide health care educators an understanding of how the use case-based examinations with their students to foster greater learning, thereby, possibly improving patient care and limiting medical error for the population as a whole.

Additionally, workplace training professionals who utilize case-based examinations in organizations for employee training may also benefit from the findings of the study. The findings could provide workplace trainers an understanding of how to best utilize cased based examinations to enhance learning in the work environment, which may improve return on investment for the organization and employee satisfaction

Will I receive payment for participation? Are there costs to participate?
There are no costs or payments to you associated with participation in this study However, to acknowledge your time, you may participate in a $30 00 Amazon com raffle at the completion of the study

How will my personal information be protected?
The only personal information collected will be for the raffle and your voice on an audiotape if you elect to participate in these portions of the study However, this information will not be associated with any of your study responses and your raffle entry form will be shredded immediately after a winner has been chosen Additionally, the interview tapes will be coded to protect your identity and participants will not be asked to share identifiable information on the study responses The interview portion of the study will be administered by a doctoral student in the Adult Learning Program at the University of Connecticut who is an experienced interviewer and has no connection to the study The interviews will be transcribed by the third-party administrator and retained by the principal investigator for one-year

You should also know that the UConn Institutional Review Board (IRB) and the Office of Research Compliance may inspect study records as part of its auditing program, but these reviews will only focus on the researchers and not on your responses or involvement The IRB is a group of people who review research studies to protect the rights and welfare of research participants

Can I stop being in the study and what are my rights?
You do not have to be in this study if you do not want to If you agree to be in the study, but later change your mind, you may drop out at any time There are no penalties or consequences of any kind if you decide that you do not want to participate

Who do I contact if I have questions about the study?
Since the study will occur during a normal class period, you will have 30 minutes to make a decision if you would like to participate We will be happy to answer any question you have about this study If you have further questions about this project or if you have a research-related problem, you may contact the principal investigator, Marijke Kehrhahn at (860) 486-0248, marijkekehrhahn@uconn edu or the student investigator, Tim Speicher at (203) 895-4160, speichert@sacredheart edu If you have any questions concerning your rights as a research subject, you may contact the University of Connecticut Institutional Review Board (IRB) at 860-486-8802

Please keep the above portion of this information sheet for your records If you wish to participate in the raffle, please fill out the bottom of this sheet and deposit it in the box at the front of the room upon leaving

---

Name ______________________________
Email ______________________________

APPENDIX E

Debriefing Statement

Thank you for your participation in this study, titled: Analogical reasoning: A process for fostering learning transfer from the classroom to clinical practice. The true purpose of this study was to examine the influence of cueing interventions (prompting) on the extent and quality of learning transfer among first-year undergraduate athletic training students engaged in comparison of structurally similar patient cases for solution of a novel problem. To prevent distortion of subject responses to the experiment, the true purpose of the study was not revealed initially in the information sheet or by the administrator of the study, rather you were informed the study involved examination of cases to ascertain reading comprehension. The hypothesis of the study is subjects cued to compare multiple patient cases will demonstrate an enhanced ability to transfer their learning gained during case examination for solution of a novel problem over those not cued. Results from the study will be utilized to improve case-based instruction and student learning.

Please contact Tim Speicher, the Student Researcher at speichert@sacredheart.edu or 203-895-4160 for more information if you have additional questions. Thank you for your time and participation in the study. Additionally, if you desire to withdraw from the study or your audio taped interview, please contact the Primary Investigator, Marijke Kehrhan at (860) 486-0248 or marijkekehrhahn@uconn.edu within 48 hours.

APPENDIX F

Institutional Review Board Approvals

University of Connecticut
Office of Research Compliance

DATE: September 18, 2009

TO: Marijke Kehrhahn, Ph D
Educational Leadership, Unit 2093

Timothy Speicher, MS
15 Blue Hill Rd
Middletown, CT 06457

FROM: Claudia Carello, Ph D
Chair, Institutional Review Board
FWA# 00007125

RE: Protocol # H09-220, "Analogical Reasoning A Process for Fostering Learning Transfer from the Classroom to Clinical Practice (Main Study)"
Please refer to the Protocol# in all future correspondence with the IRB
Funding Source Investigator Out-of-Pocket
Approval Period: From: September 18, 2009 Valid Through: September 18, 2010
"Expiration Date"

On September 11, 2009, the Institutional Review Board (IRB) reviewed the above-referenced research study by expedited review, and determined that modifications were required to secure approval Those requirements have been met, and the IRB granted approval of the study on September 18, 2009 The research presents no more than minimal risk to human subjects and qualifies for expedited approval under category # 7 - Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies

Enclosed is the validated information sheet, which is valid through September 18, 2010 **A copy of the approved, validated information sheet (with the IRB's stamp) must be used to consent each subject.**

As a reminder, please provide copies of the IRB approval from Sacred Heart University, Central Connecticut State University and from Quinnipiac University

Per 45 CFR 46 116(d), the IRB approved the consent procedure outlined in the protocol involving use of deception, thereby altering some elements of informed consent The IRB finds and

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documents that (1) the research involves no more than minimal risk to the subjects, (2) the waiver or alteration will not adversely affect the rights and welfare of the subjects, (3) the research could not practicably be carried out without the waiver or alteration, and (4) whenever appropriate, the subjects will be provided with additional pertinent information after participation

Per 45 CFR 46 117(c)(2), the IRB waived the requirement for the investigator to obtain a signed consent form for the subjects because it found that the research presents no more than minimal risk of harm to subjects and involves no procedures for which written consent is normally required outside of the research context

All investigators at the University of Connecticut are responsible for complying with the attached IRB "Responsibilities of Research Investigators"

Re-approval It is the investigator's responsibility to apply for re-approval of ongoing research at **least once yearly**, or more often if specified by the IRB The Re-approval/Completion Form (IRB-2) and other applicable re-approval materials must be submitted **one month** prior to the expiration date noted above

Modifications If you wish to change any aspect of this study, such as the procedures, the consent forms, the investigators, or funding source, please submit the changes in writing to the IRB using the Amendment Review Form (IRB-3) All modifications must be reviewed and approved by the IRB prior to initiation

Audit All protocols approved by the IRB may be audited by the Research Compliance Monitor

Please keep this letter with your copy of the approved protocol

Attachments

1 Validated Information Sheet
2 Validated Debriefing Statement
3 Validated Appendix A
4 Validated IRB-1
5 "Responsibilities of Research Investigators"

HUMAN STUDIES COUNCIL
CCSU
Central Connecticut State University

CCSU Federalwide Assurance #: FWA00005627
CCSU IRB registration #: IRB00003671

Timothy Speicher
15 Blue Hill Rd.
Middletown, CT 06457

Marijke Kehrhahn, Ph.D.
University of Connecticut
NEAG School of Education
249 Glenbrook Rd. Unit 2064
Storrs, CT 06269

September 30, 2009

Dear Dr. Kehrhahn and Mr. Speicher,

This is to inform you that your HSC proposal #F09017 entitled "Analogical reasoning: A process for fostering learning transfer from the classroom to clinical practice" has been approved by the Human Studies Council at Central Connecticut State University. You are authorized to use CCSU students as subjects for this research.

This approval is subject to continuing review or renewal on or before September 30, 2010. Please note that any changes to the study must be promptly reported and approved. Contact either Dr. Bradley Waite (**Waite@ccsu.edu** 832-3115) or Mimi Kaplan (**Kaplan@ccsu.edu** 832-2366) if you have any questions or require further information.

Best of luck with the research!

Sincerely,

Bradley M. Waite
Chair, Human Studies Council

CC: P. Morano
HSC file

1615 Stanley Street — PO Box 4010 — New Britain, CT 06050-4010 — T 860-832-2366 — F 860-832-2352 — www.ccsu.edu

QUINNIPIAC UNIVERSITY

September 22, 2009

Dr. Lenn Johns
School of Health Sciences
EC-TRN

Dear Lenn,

Upon review by our Human Experimentation Committee/Institutional Review Board (HEC/IRB), the proposal submitted by Dr. Marijke Kehrhahn and Professor Tim Speicher from the University of Connecticut entitled ***Analogical Reasoning: A Process for Fostering Learning Transfer from the Classroom to Clinical Practice*** has been assigned Protocol # **4409** and approved under an exemption from Federal regulations 45 CFR 46. Please understand that should any of the protocol elements change, the HEC/IRB should be notified immediately.

Sincerely,

Joseph J. Woods, Ph.D.
Chair, Quinnipiac HEC/IRB

275 Mt Carmel Avenue, Hamden, CT 06518-1908 Tel 203-582-8200 www.quinnipiac.edu

SACRED HEART UNIVERSITY

SACRED HEART UNIVERSITY
Institutional Review Board (IRB)
for Research Involving Human Subjects

DATE:		September 24, 2009
TO:	**Name**	Tim Speicher, MS, ATC, LAT, CSCS
	Address	Physical Therapy and Human Movement and Sports Science
	Telephone	203- 396-8012
FR:	**Name/Title**	Dr Stephen Lilley
	Address	Sociology Department
	Telephone	203-371-7761
RE:	**Proposal**	Analogical reasoning A process for fostering learning transfer from the classroom to clinical practice (Main Study)

__X The IRB has reviewed and approved the above-referenced proposed project Please honor the following requirements when conducting your study

- At all times, minimize risks to subjects
- Any significant change in procedure that may impact subjects must first be approved by the IRB
- Insure adequate safeguarding of sensitive data during the study, and destroy sensitive material when the study is completed
- If the study continues beyond one year, an annual review form must be filed with the IRB
- If results are disclosed to subjects, agencies, etc , make sure that the findings are disclosed in such a manner that confidentiality is protected

cc Virginia Harris, IRB Secretary